Perceptions of Ecosystem Services across Diverse Cultures and Ecosystems

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For my parents, for your unfailing love and support.
And for the family I found in Zürich, you caught me by surprise.

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Summary

Ecosystem services is a young field that has been expanding exponentially for the last 20 years. This expansion has meant many questions and gaps continue to be revealed, not least how individuals perceive ecosystems, the dependencies that humans have on them, and the value of the contributions that nature makes to our their lives. Understanding perceptions is essential for facilitating the adoption of ecosystem services research outputs into policy mechanisms, and to better inform research directions.

In the following study, I explore perceptions of experts from research and management across eight globally distributed research sites across four continents, to uncover how they perceive those ecosystems and human dependencies on them. I first give a General Introduction, which outlines key themes related to global change, biodiversity and ecosystem services. I also give detail about the research locations included in this study and the questions I seek to answer.

In Chapter 1, I establish baselines of ecosystem services through 103 interviews with stakeholders within each location. Using presence/absence and importance scale responses from interviewees I test whether these baselines are unique to each site, and assess whether there are similarities between sites and with how services are perceived across the sites.

In Chapter 2, I explore services that elicit uncertainty and disagreement from interviewees from Chapter 1. I use the service itself and attributes of the interviewees to determine whether these can predict uncertain answers, and areas of disagreement. As this chapter compares individual responses at sites, I restrict my data to two sites with higher numbers of interviewees.

In Chapter 3 I use text analysis techniques to explore the interview notes and transcripts to uncover values that interviewees express about the research sites. The responses are framed around questions about ecosystem services the sites provide, offering greater detail and insight into how interviewees relate to each location.

Finally, in Chapter 4 I take a narrative form, using the words of the interviewees to describe how people live and interact with the research locations, and how they are adapting to changing conditions. The chapter was written as part of a public outreach project, *Klimagarten 2085*, which explored human adaptations to climate change.

In the General Discussion I draw broader conclusions about the key findings and wider relevance of this work, as well as outlining future directions..

Zusammenfassung

Die Untersuchung von Ökosystemdienstleistungen ist ein junges Forschungsfeld, das in den letzten 20 Jahren exponentiell expandierte. Diese Zunahme hat viele Fragen und Lücken aufgezeigt, nicht zuletzt, wie Stakeholder Ökosysteme wahrnehmen, wie der Mensch von ihnen abhängt, und welche Werte die Natur für unser Leben hat. Das Verständnis der Wahrnehmungen ist wesentlich für die Erleichterung der Übernahme von Forschungsergebnissen zu Ökosystemdienstleistungen in politische Agenden und als fundierte Information für verschiedene Forschungsrichtungen. In der folgenden Studie untersuche ich in acht global verteilten Forschungsstandorte, wie Experten aus Forschung und Management die lokalen Ökosysteme und ihre Abhängigkeiten davon wahrnehmen. Ich gebe zunächst eine Allgemeine Einführung, die Schlüsselthemen in Bezug auf globale Veränderungen, Biodiversität und Ökosystemdienstleistungen aufzeigt, gehe detailliert auf die Forschungsstandorte in dieser Studie ein und formuliere die Fragen, die ich beantworten möchte.

In Kapitel 1 verwende ich Präsenz/Absenz und Wichtigkeitsskalenantworten von 103 Befragten, um die Ökosystemleistungen zu erfassen, die von jedem Standort bereitgestellt werden. Ich prüfe, ob diese für jeden Standort einzigartig sind oder ob es Ähnlichkeiten zwischen ihnen gibt und wie die jeweiligen Ökosystemdienstleistungen wahrgenommen werden.

In Kapitel 2 verwende ich die Daten wie in Kapitel 1, um die Leistungen zu untersuchen, bei denen es Unsicherheit oder Uneinigkeit bei den Befragten gab. Ich analysiere die Ökosystemdienstleistung selbst und die Eigenschaften der Befragten, um festzustellen, ob ich unsichere Antworten und Meinungsverschiedenheiten vorhersagen kann. Da dieses Kapitel individuelle Antworten von verschiedenen Standorten vergleicht, beschränke ich mich auf Daten von zwei Orten mit einer höheren Anzahl von Befragten.

In Kapitel 3 nutze ich Textanalysetechniken, um die Interviewantworten auf die Werte zu untersuchen, die die Befragten über die Forschungsstandorte äußern. Die Antworten beziehen sich auf Fragen zu den Ökosystemleistungen, die von den Forschungsstandorten bereitgestellt werden, und bieten mehr Details und Einblicke in die Beziehung der Befragten zu den einzelnen Standorten.

Schliesslich verwende ich in Kapitel 4 eine erzählerische Form und benutze die Worte der Befragten, um zu beschreiben, wie Menschen mit den Forschungsstandorten leben und interagieren und wie sie sich an veränderte

Bedingungen anpassen. Das Kapitel wurde im Rahmen eines Öffentlichkeitsprojekts, Klimagarten 2085, geschrieben, welches die menschlichen Anpassungen an den Klimawandel untersucht.

In der Allgemeinen Diskussion ziehe ich generelle und weiterführende Schlussfolgerungen über die wichtigsten Ergebnisse, erläutere die Relevanz dieser Arbeit und zeige zukünftige Forschungsrichtungen auf.

General Introduction

1 Research Justification

'We have to remain focused on the benefits provided by ecosystems, remembering that the degree to which the public perceives and understands them is a separate (and very important) question.' (Costanza, 2008)

Given the need to integrate better knowledge about beneficiaries in ecosystem services research, in this study I explore the perceptions of researchers and site experts. Over the four chapters, I look at different facets of their perceptions in relation to the ecosystem services provided at specific research sites. This allows me to better understand three key aspects of ecosystem services in relation to the sites.

Firstly, when considering ecosystem services anywhere, we need to know which baselines to work from. It is possible to have a general idea of the ecosystem services provided by any location based on the biome, ecosystem type, and land uses. This can be done through airborne survey and remote sensing for example. However, this does not provide information on how beneficiaries perceive their multiple dependencies on nature. Exploring perceptions uncovers the services we cannot observe, and adds detail to those we can, giving better baselines of services.

Secondly, in this study I analyse responses from experts who are researchers and managers directly associated with the research sites. This provides contrasting views, and while this is a focussed sample of actors, it has allowed me to have easy access to interviewees. This access has led to better knowledge, connections and opportunities for future work with a wider representation of stakeholders for each site.

Thirdly, exploring the values that interviewees express for specific sites in the context of ecosystem services is an important step towards defining the different dimensions of value, and connecting these to ecosystem services. It acknowledges that multiple values are held by individuals for ecosystem services, and for the places from which those services derive. Recognising and embedding multiple values in ecosystem service assessments and in any work that aims to assist in decision-making is essential. Ignoring the many values people hold for localities risks threatening people's identities and creating unnecessary conflict through possibly poorly informed management decisions. The importance of this is currently reflected in debates about fully engaging with indigenous and local knowledge in IPBES (Tebtebba, 2013; WWF, 2013; Stockholm Resilience Centre, 2015; IPBES Secretariat, n.d.)

Finally, I attempt to look at perceptions of ecosystem services, the uncertainties and disagreements around them, and the values that people hold for place, not only in one location, but also in multiple locations across biomes. This is one of very few studies to do so.

2 Research Questions

While each chapter of this study deals with specific research questions, there are over-arching questions that guide the direction of the thesis, and the specific questions of each chapter.

Ecosystem services is a broad field of enquiry, as has been described above, and leaving aside immediate management or policy issues, I approach this on a theoretical level to understand what individuals both mean and understand by ‘ecosystem services’.

My key questions have centred on discovering whether it is possible to establish baselines of ecosystem service provision for any given site through expert interviews alone, and without the need for more complex data collection and assessment (Chapter 1). I then wanted to determine where individuals reveal difficulties in understanding terms and concepts about both ecosystem services (Chapter 2). While these two questions allowed for an empirical approach, I also wanted to analyse the interview responses in greater detail to explore the language that individuals used about the research sites and their relationships to them (Chapter 3). Finally, I was curious to know whether the interviews for each site, taken together, could form a narrative for each site about the dependencies and adaptations that they engender in individuals and communities (Chapter4).

3 Background

Biodiversity is declining world-wide as impacts of global change intensify (Parmesan and Yohe, 2003; IPCC, 2013; Dirzo et al., 2014). While extensive, detailed, system-wide knowledge is still lacking, we know that biodiversity declines directly affect how ecosystems function (Gamfeldt et al., 2013) and the ability of ecosystems to support life (Cardinale et al., 2012; Allan et al., 2015). The resulting risks to human lives and livelihoods from the impacts of biodiversity loss and global change (Mace et al., 2015; Steffen et al., 2015) include, but are not limited to; drought, leading to reduced food security (Wheeler and von Braun, 2013); loss of coastal lands due to rising sea levels (IPCC, 2013; Hauer et al., 2016); increased, localised flooding from extreme precipitation events (Madsen et al., 2014); and rapid, unpredictable wildfire damaging natural, agricultural and urban areas (Abatzoglou and Williams, 2016).

These threats to biodiversity and human well-being have increased research effort into causes, consequences and impacts of global change now and into the future. There are numerous approaches employed to build the multiple evidence base that is needed to do this (Clark et al., 2011), such as ecosystem functioning studies (Balvanera et al., 2006; Díaz et al., 2007; Hector and Bagchi, 2007), resilience and sustainability science (Holling, 1973; Folke et al., 2016; Cumming and Allen, 2017), planetary health research (Ostfeld, 2017); biocultural studies (Sterling et al., 2017); and ecosystem services work (Costanza et al., 1997; World Resources Institute, 2005a; Braat and de Groot, 2012). Supporting these are tools and methods, which include but are not limited to, modelling scenarios (Drijfhout et al., 2015; Kok et al., 2017; Rosa et al., 2017), participatory decision-making (Reed, 2008; Etienne et al., 2011), use of remote sensing data (Braun, 2017; Vihervaara et al., 2017), integration of indigenous and local knowledge (ILK) (World Resources Institute, 2005b; Braat and de Groot, 2012; Alkemade et al., 2014), and ecosystem management techniques (Christensen et al., 1996; Lindenmayer et al., 2007; Plummer et al., 2012). This effort is driven and supported by a plethora of science and science-policy platforms that have developed over the last 30 years, including the Intergovernmental Panel on Climate Change (IPCC), the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES), the Convention on Biological Diversity (CBD), and the Sustainable Development Goals (SDGs). Further, indigenous and local knowledge are increasingly recognised as integral to understanding human dependencies on nature, with greater effort is invested in integrating them in ecosystem services work (WWF, 2013). As approaches become more inclusive, there is also a need to have a multifaceted understanding of the values that people hold for place and for nature (Chan et al., 2016). Whether these multiple approaches and agreements will be successful in halting biodiversity loss remains to be seen (Tittensor et al., 2014) but understanding what is happening, to whom and where remains a central theme of global change, biodiversity and ecosystem services research.

4 Global Change

Global Change refers to shifts in life and climate on Earth, brought about through both human activity and natural phenomena. The definition given by the International Geosphere-Biosphere Programme is:

> *'planetary scale changes in the Earth system. The system consists of the land, oceans, atmosphere, poles, life, the planet's natural cycles and deep Earth processes. These*

constituent parts influence one another. The Earth system now includes human society, so global change also refers to large-scale changes in society…' (International Geosphere-Biosphere Programme, 2015)

Transitions in the earth system can therefore be due to entirely natural drivers, occurring at multiple time and spatial scales (Hughes et al., 2013). Some drivers originate beyond the earth's boundaries, for example periodic warming from oscillations in the orbit around the sun (Crampton et al., 2018), and fluctuations in solar radiation (Rozanov et al., 2016). Other drivers occur within the bounds of the planet, originating from the atmosphere, land, and oceans (Jenkyns, 2003). Examples of this include the opening and shutting down of deep ocean thermal vents, which affect the temperature and chemical composition of ocean waters (Reed et al., 2015; Downes et al., 2016), or wildfires releasing carbon dioxide and particulate matter into the atmosphere and radically altering local vegetation (Liu et al., 2014). The scale of these impacts can be anywhere from short-term, localised effects (the loss of forest due to wind damage (Everham and Brokaw, 1996)), to changes that take place over hundreds or thousands of years (erosion of coastal land (Cambers, 1976)) and across huge regions of the planet (climate forcing by sulphur deposition from volcanic eruptions (Zielinski et al., 1994)). The impacts of these events may be felt locally, for example by coastal communities that lose homes and livelihoods; regionally, as dust clouds from volcanic eruptions cover large areas, depositing ash and restricting travel; and globally, as el Niño drives cyclones, warms northern oceans, and intensifies storm and drought events.

Just as any other organism impacts and shapes the environment around it (Vitousek, 1997), human activities drive changes in the planetary system (Rockström et al., 2009; Steffen et al., 2015). Steffen and others have discussed in a number of papers how pre-agricultural societies shaped the earth system at local, regional and possibly even continental scales, particularly through the use of fire, the development of tools and hunting technologies, with the later domestication of animals and plants. They also discuss the extent to which forest clearance and development of rice paddy increased atmospheric gas concentrations and consequently prevented an ice age around 8-5000 years ago (Ruddiman, 2003; Steffen et al., 2007; Smith and Zeder, 2013). However, the impact of humans since industrialisation, with the increase in use of fossil fuels alongside rapid population growth, has become a global phenomenon (Vitousek, 1997; Steffen et al., 2011), and ecosystems have become human-dominated, not just human influenced (World Resources Institute, 2005b). As stated by Folke, '*humans have become a significant force* *in the dynamics of the Earth system at the planetary level'*, (Folke et al., 2016). As a result of this rapid increase in human activity that visibly alters planetary processes, the end of the relatively benign Holocene period, our current geological period, has been labelled the Anthropocene. Popularised at the start of this century by atmospheric chemist Paul Crutzen and ecologist Eugene Stoermer (Crutzen, 2002; Crutzen and Stoermer, 2000), the term has yet to be officially recognised as a geological period. Discussion is on-going about how to delineate between the stratigraphic designations (Smith and Zeder, 2013; Lewis and Maslin, 2015; Ruddiman et al., 2015; Waters et al., 2016), and how to fully define the epoch across disciplines (Ellis et al., 2016). However, the term is increasingly used in global change research (Steffen et al., 2011; Corlett, 2015; Kanngieser, 2015; Folke et al., 2016).

Current anthropogenic drivers of global change include climate change driven by human activity; land conversion for agriculture, forestry, and urban development; introductions of invasive species; over-exploitation of natural resources; and increased deposition of pollutants from agricultural and industrial processes. Impacts of these drivers threaten the resilience and functioning of terrestrial and marine ecosystems. Examples include increased pathogens in monoculture and climate affected forests, reducing the ability of vegetation to absorb CO_2 and transpire oxygen and water vapour (Scarascia-Mugnozza et al., 2000; Dale et al., 2001); less effective flood control in modified watersheds (Gao et al., 2017); ground nesting bird losses from introduced predators (Harper and Bunbury, 2015); reduced seed dispersal from over-hunting wild animals (Harrison, 2011; Ripple et al., 2016); damage to sea floors and coral reefs from fishing activities (Barbier, 2014); and eutrophication of sources of drinking water (Conley et al., 2009). Levels of biodiversity at relevant scales influence ecosystems responses to these multiple threats from both natural and anthropogenic global change drivers (Isbell et al., 2015a; Oliver et al., 2015).

5 Biodiversity

There are numerous definitions of biodiversity but the Millennium Ecosystem Assessment (MA) and the Convention on Biological Diversity (CBD) give the two that are most relevant in the context of this project:

> *"…the variability among living organisms from all sources, including terrestrial, marine, and other aquatic ecosystems and the ecological complexes of which they are part….it is the … layer of living organisms that occupy its surfaces and its seas - biosphere*

connecting atmosphere, geosphere, hydrosphere into one environmental system" (World Resources Institute, 2005a)

The MA expands this definition by describing a number of levels of biodiversity (table 1).

Level	Importance of Variability	Importance of Quantity and Distribution
Genes	adaptive variability for production and resilience to environmental change, pathogens, and so on	local resistance and resilience
Populations		local provisioning and regulating services, food, fresh water
Species	the ultimate reservoir of adaptive variability, representing option values	community and ecosystem interactions are enabled through the co-occurence of species
Ecosystems	different ecosystems deliver a diversity of roles	the quantity and quality of service delivery depend on distribution and location

Table 1: Levels of biodiversity described in the Millennium Ecosystem Assessment (World Resources Institute 2005b).

The CBD is a little more succinct:

“"Biological diversity" means the variability among living organisms from all sources including, inter alia, terrestrial, marine and other aquatic ecosystems and the ecological complexes of which they are part; this includes diversity within species, between species and of ecosystems.” (Secretariat of the Convention on Biological Diversity (SCBD), n.d.)

Quantifying any of these levels of biodiversity – how much and where - and how these change in time and space – is consequently highly complex (Anderson 2018). How biodiversity is organised, and how organisms interact determine biome types, and ecosystem processes and functions within those biomes. This is further complicated by an uneven global distribution of biodiversity (figure 1).

While biodiversity and ecosystem processes are intrinsically bound together, our understanding of the mechanisms involved is incomplete. There is evidence that increased biodiversity increases productivity in grassland systems (Hector, 1999; Weigelt et al., 2010; Zuppinger-Dingley et al., 2014; Isbell et al., 2015a), however, the strength of effects, impacts on resilience and stability, and whether diversity positively or negatively affects ecosystem recovery is less clearly defined (Balvanera et al., 2006). Species, and to some extent genetic diversity in grasslands are quite well studied (Scherber et al., 2010). However, given the levels of organisation in table 1, and the multiple scales, locations and ecosystems in which these can be studied (Chase and Leibold, 2002), we are far from being able to generalise about the role of biodiversity in ecosystem processes and functions (Hooper et al., 2005).

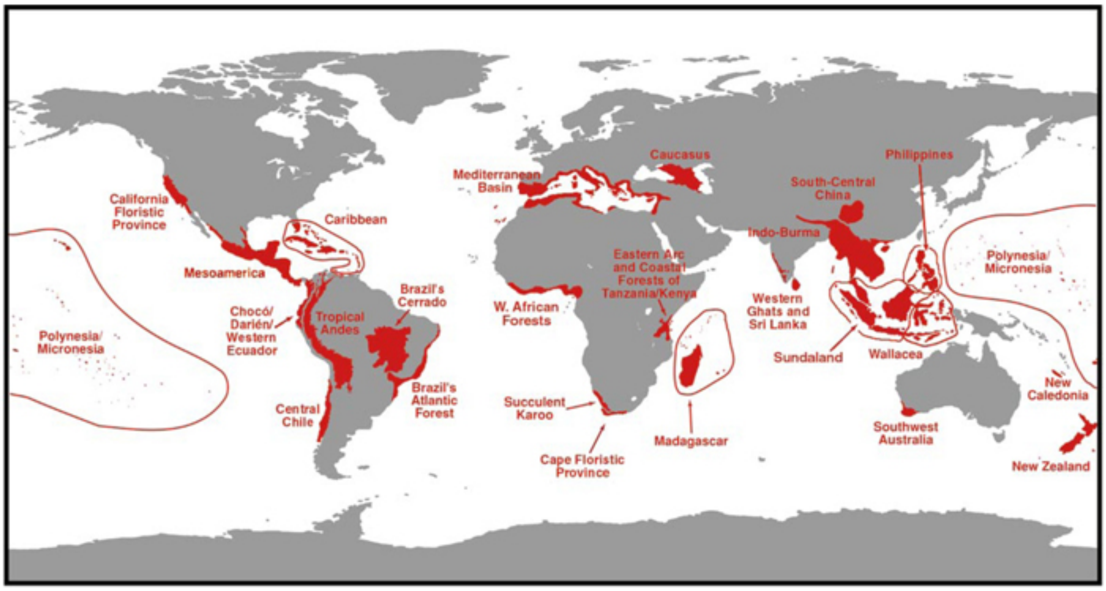

Figure 1: Map of global biodiversity hotspots, from (Myers et al. 2000). Red colouring shows locations of areas of high biodiversity.

6 Ecosystem Services

Changes to the earth system and the biodiversity that determines and is determined by ecosystem processes and functions, directly affect human well-being. This is not a new understanding and has been articulated in diverse ways throughout human existence. While many academic disciplines focus on human society and how it interacts with the natural environment, it is the field of ecosystem services that has emerged in the effort to quantify and value our dependencies on the earth system. Ecosystem services and benefits derived from them have been variously defined as:

> *…the benefits people obtain from ecosystems. These include provisioning services such as food, water, timber, and fiber; regulating services that affect climate, floods, disease, wastes, and water quality; cultural services that provide recreational, aesthetic, and spiritual benefits; and supporting services such as soil formation, photosynthesis, and nutrient cycling.* Millennium Ecosystem Assessment, (World Resources Institute, 2005b)

> *…the "usefulness" of biodiversity…. They illustrate the link between, on the one hand, the interactions of species with each other and with the physical environment; and on the other, the well-being of people, whether in terms of wealth, nutrition or security.*

Convention on Biological Diversity (Secretariat of the Convention on Biological Diversity (CBD), n.d.)

…the direct and indirect contributions of ecosystems to human well-being. The Economics of Ecosystems and Biodiversity (TEEB), (Kumar, 2010)

6.1 Historical Development

References to and an understanding of the interdependence between humanity and the environment are not new in ecological and environmental literature. Examples are Aldo Leopold discussing the inter-relationship between people and the land in *A Sand County Almanac* (Leopold, 1949), Rachel Carson connecting environmental and human health in her influential work *Silent Spring* (Carson, 1962), Paul and Anne Ehrlichs' description of ecosystems and humanity's place within them (Ehrlich, 1970), expanded further in Edward O. Wilson's exploration of the biophilia concept (Wilson, 1984) and later humanity's responsibility to conserve biodiversity (Wilson, 2001). Other voices include Stephen R. Kellert with his further work on biophilia and the value of nature (Kellert, 1996) and the approach taken by the Kaplans to manage the environment for people (Kaplan, 1998). These writers do not use the term ecosystem services but their work contributes to the development of the concept.

The coining of the term ecosystem services can be attributed to Paul and Anne Ehrlich in 1981 (Ehrlich, 1970; Ehrlich and Ehrlich, 1981; Braat and de Groot, 2012), drawing on earlier concepts of natural capital elucidated by environmental economist E. F. Schumacher (Schumacher, 1973). Gretchen Daily's book 'Nature's Services: Societal Dependence on Natural Ecosystems' and Paul Costanza's seminal 1997 paper, further elucidated and popularized the concept, facilitating its adoption in research, policy and practice (Costanza et al., 1997; Daily, 1997). These two works in particular led to a rapid increase of research in the field of ecosystem services (figure 2), in the attempt to understand how the world's natural resources are exploited and valued by human populations.

In 1992, sustainable development was on the political agenda at the Rio Earth Summit, as it was central to the three UN conventions. The United Nations Framework Convention on Climate Change (UNFCCC) was adopted in 1992 as an international commitment to meet the challenges of climate change. The Convention on Biological Diversity (CBD), entered into force in 1993 and signatories agree to its three main objectives of conserving biological diversity, sustainable use of components of biodiversity, and fair and equitable sharing of any benefits derived from genetic resources. The United Nations Convention to Combat Desertification (UNCCD), was established a year later, with its key objective of avoiding, minimizing , and reversing desertification in drylands. These three conventions put into international policy agreements the need to understand globally which resources were being used, how they were being used and by whom, what the implications were for people and the environment, and who was paying for them, if at all. This was the time for ecosystem services to come to the fore and the 1997 Costanza paper was timely.

Adoption of the three conventions – along with the picture created by Costanza - clarified the need to form a global overview of the state of biodiversity and key knowledge gaps. This led to the publication in 2005 of the Millennium Ecosystem Assessment (Millenium Ecosystem Assessment (MA), 2005). This clarified that understanding the economic value of biodiversity and ecosystems is far more complex than Costanza might have implied – or perhaps as complicated, and was backed up by the publication of the Stern Review on the Economics of Climate Change in 2006 (Stern and Great Britain, 2007), outlining the costs of doing nothing.

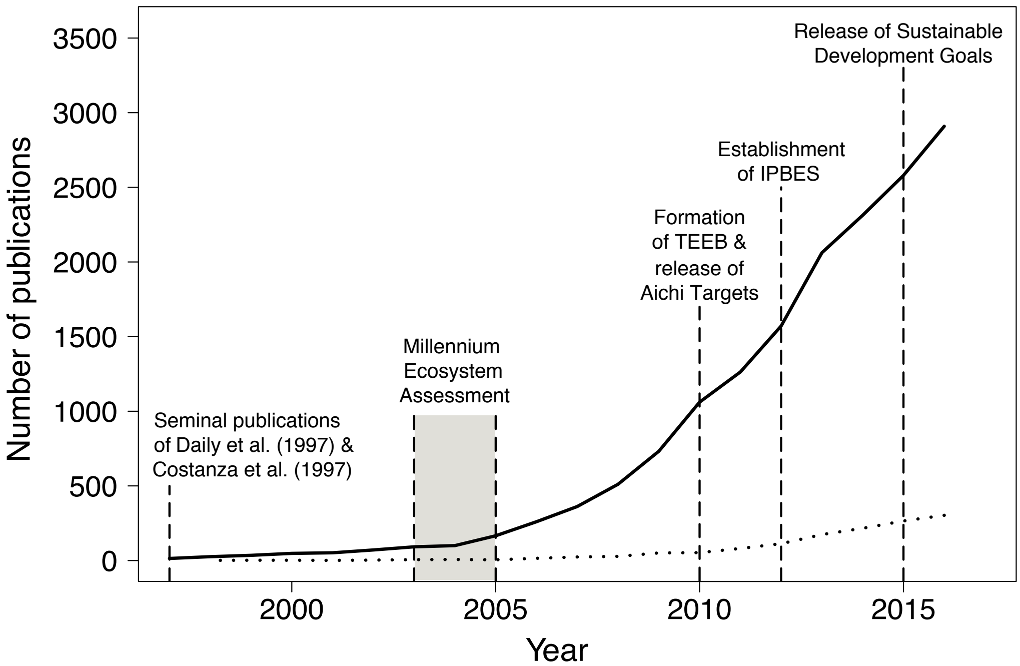

Figure 2: Time line of ecosystem services publications from 1997 until 2016 based on Scopus: published articles with “ecosystem service*” (solid line) and with “ecosystem service*” & map* (dotted line) in the article title, keywords or abstract. Vertical dashed lines indicate important dates of publications and policy decisions that fostered ecosystem services research. Reproduced with permission from D. Braun, unpublished thesis introduction (Braun, 2017).

These taken together created the impetus for leaders of the G8+5 nations to meet in Germany in 2007 to develop TEEB (The Economics of Ecosystems and Biodiversity), with an interim report published a year later (Sukhdev, 2008). The platform focuses on the value of biodiversity and costs of biodiversity loss, within the frame of the CBD and its strategic goals to 2020.

The strategic biodiversity goals, agreed at Aichi in 2010, set the political and research agenda to 2020 (Cardinale et al., 2012; Convention on Biological Diversity, n.d.). Of these, goal D specifically references ecosystem services, and targets 14 & 15 stress the need for ecosystems to be restored and resilient. This has been translated into the EU Biodiversity strategy for 2020 and the mapping and reporting framework was published in 2013 (Maes et al., 2013). Key issues for achieving the Aichi targets on ecosystem services include:

1. Detecting and quantifying ecosystem services.
2. Scaling by linking plot and landscape scale between and within ecosystems.
3. Identifying synergies and trade-offs, requiring work with focus groups and use of participatory GIS for scenario building to address Social-Ecological Systems (SES).
4. Linking data and taking a transdisciplinary approach to data sharing.

6.2 The Emergence and Implications of IPBES

The impetus for better understanding of global change and its impact on humanity that drove many of the key events outlined above, led in 2012 to the first meeting of the Intergovernmental Platform on Biodiversity and Ecosystem Services (IPBES). This platform, while very young, aims to be on a par with the Intergovernmental Panel on Climate Change (IPCC), which has been instrumental in building the science consensus behind climate change and in communicating the impacts of this with governments around the world. The establishment of a similar platform for biodiversity and ecosystem services is a positive indication of the political will to understand biodiversity change, and how it impacts and is impacted by humanity. The 2016 publication of the Sustainable Development Goals (SDGs), along with the CDB Aichi targets outlined above, has enhanced the need for better engagement with and integration of sustainability and ecosystem services research. This includes supporting and developing inter- and transdisciplinary approaches that facilitate the production of research that is accessible and relevant at appropriate scales. It also requires a different approach to the types of knowledge used for assessments, something that IPBES has struggled with since its inception, as illustrated by its conceptual diagram, developed from the original MA one (figure 3) (Díaz et al., 2015a).

Specifically, once human well-being is considered, factors such as resource rights, cultural appropriation, power relations and traditional livelihoods cannot be ignored by researchers or decision makers. In early 2018, at its sixth plenary, IPBES contributors opened the debate within this natural science and economics dominated community about redefining ecosystem services. This led to use (amongst lengthy discussion (Braat, 2018; Díaz et al., 2018; Peterson et al., 2018)) of the term 'Nature's Contributions to People' (NCP). It is used in IPBES assessments from 2018 and the authors of the first paper to promote the term in relation to IPBES, explain why it necessary:

First, the NCP approach recognizes the central and pervasive role that culture plays in defining all links between people and nature. Second, use of NCP elevates, emphasizes, and operationalizes the role of indigenous and local knowledge in understanding nature's contribution to people (Díaz et al., 2018).

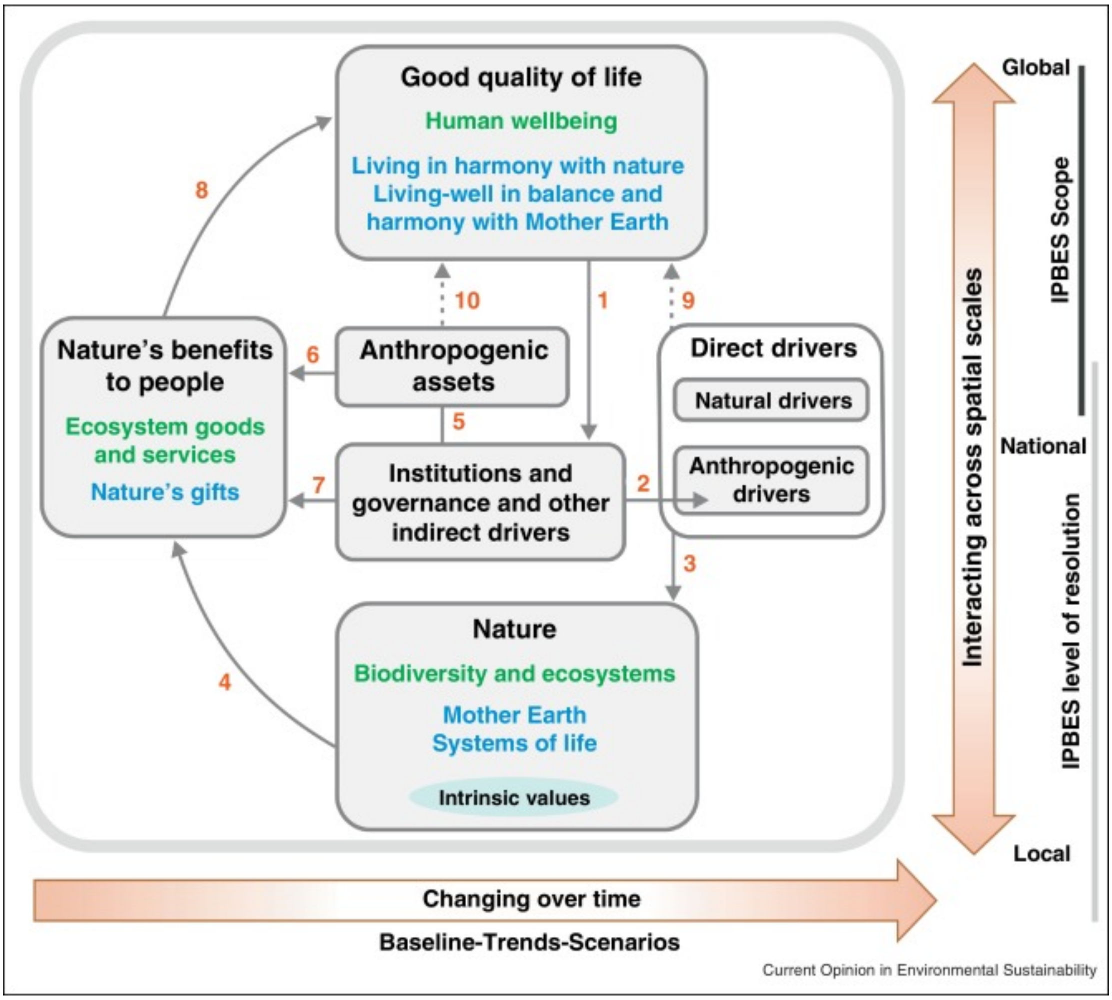

Figure 3: IPBES conceptual diagram showing the links between quality of life, nature and its gifts, drivers of change, and the institutions that connect them. Reproduced from (Díaz et al. 2015).

As this development illustrates, the field of ecosystem services is rich, complex and evolving.

6.3 Details and Research Areas

The MA lists four ecosystem service categories:

Provisioning services: the supply of goods of direct benefit to people, often with a clear monetary value, such as timber from forests, medicinal plants, and fish from oceans, rivers and lakes.

Regulating services: the range of functions carried out by ecosystems, often of great value but generally not given a monetary value in conventional markets. Examples include climate regulation through carbon storage, removal of pollutants through air and water filtration, and protection from landslides and coastal storms.

Cultural services: do not provide direct material benefits but contribute to the wider needs and desires of society. Examples include the spiritual value attached to particular ecosystems such as sacred groves, and the aesthetic beauty of landscapes or coastal formations that attract tourists.
Supporting services: not of direct benefit to people but essential to the functioning of ecosystems and therefore indirectly responsible for all other services. Examples are soil formation and processes of plant growth. Supporting services are often either included within regulating services or are considered as components of ecosystem functioning, such as photosynthesis, essential for primary productivity, from which we benefit in terms of crop and timber production, for example. This category of services are now generally considered as subordinate and are not explicitly listed separately (Haines-Young and Potschin, 2012)

In order to quantify the services defined in classification systems such as the MA or in the Common International Classification of Ecosystem Services (CICES) (Haines-Young and Potschin, 2012), research effort has been given to identifying indicators for each, or for bundles of services. This is necessary, if we wish to know how much of a service is both available and in use. For example, the number of urban community gardens can be used to estimate food supply. Selection of indicators to then extrapolate service supply (actual or potential) is understandably far from complete. Issues related to scale (temporal and spatial), site context and feasibility make it difficult to ascertain clear, generalised indicators for each service. Scale is also problematic as services are interdependent, extend over large areas, supplied from discrete locations to distant beneficiaries, and fluctuate in their temporal extent. Many services, particularly cultural, are understood and experienced very differently depending on socio-political contexts. In addition, different methods struggle to find complementarity in scales. For example, large-scale remote sensing data is difficult to map to local, fine-scale biodiversity records. Assessing how much of something is available under which conditions relies to an extent in understanding the trade-offs between competing demands. Increasing the supply of drinking water from a watershed may lead to reduced supply for fisheries or more restrictive access for recreation, for example. To have some idea of what the trade-offs are, data from mapping, biodiversity recording and quantification of services through indicators are used to create scenarios. This is a key component of ecosystem services research, which helps to offer projections of how land-use and climate change impact ecosystem service supply and builds building on climate scenarios from the IPCC. However, there are large uncertainties within these – from the ground-truthing of base maps, to knowledge of past states and predictions of future climatic conditions. At best, predictions from scenarios are heuristic, although they provide much needed baseline projections for land-use planning.

These are all details related largely to bio and geophysical states, however, ecosystem services are fundamentally about people and the decisions that we make. Economics, at its most basic level, is the field that explores human behaviour and decision-making, using monetary metrics to ascertain how much value we place on something. The use of economic valuation techniques in ecosystem services work has been hotly contested, despite our age-old use of monetary exchange mechanisms as an expression of the importance we place on the goods we take from nature. Understanding the financial costs of managing a protected area, and the real benefits to human well-being that those costs are providing, is essential for managers and decision makers. No less important is the need to understand the costs of land use practices (e.g. water extraction). There is very clearly a place for monetary valuation, or accounting, in ecosystem services research that is directly applicable for on the ground decision-making.

However, as ecosystem services aim to represent our multiple dependencies on nature, there is also a need to directly engage with people and understand the motivations behind the decisions we make (Reed, 2008; Tengö et al., 2014). This gives rise to the large body of work that uses information from and engagement with various stakeholders in ecosystem service assessments. This is where there is space and opportunity to integrate better with sustainability and socio-ecological systems science (Reed, 2008; Folke et al., 2016). Agent-based modelling techniques (Matthews et al., 2007; Chen et al., 2012), citizen science projects (Ahern et al., 2014; Buytaert et al., 2014), stakeholder fora (Buijs et al., 2011), choice experiments (Chan et al., 2015), and questionnaires and guided interview techniques (Klain et al., 2014; Ksenofontov et al., 2017; Nielsen-Pincus et al., 2017) are just some of the methods employed.

7 Research Sites

There are eight research sites in this project (figure 4), and each is a nested socio-ecological system (figure 5).

The research sites have all been selected for inclusion in the University of Zürich Research Priority Programme, Global Change and Biodiversity (URPP GCB), although since this study started, Pasoh is no longer included and the Swiss National Park has been added.

Figure 4: Map of research sites covered by this study

The URPP GCB is a 12-year programme to investigate the impacts of global change on biodiversity and ecosystem functioning at multiple scales. A key objective is to understand the feedback mechanisms between biodiversity and other global change drivers. The research sites have been selected because they represent a suite of globally distinct ecosystems at different latitudes and scales, with varied land-use types, human populations, and socio-political conditions. The sites have established research infrastructure, alongside research memoranda of understanding that allow University of Zürich access to them. These factors facilitate the integration of different researchers, approaches and methods, and the comparison of feedbacks and impacts across the sites. With regard to this study, it is possible to investigate whether human societies derive different benefits from each site at different scales.

As the sites vary considerably, it is important to define the site boundaries to put them in ecological and decision-making contexts, and consequently better understand the ways that services and benefits are perceived by interviewees. While a natural science perspective may consider that the ecological context of the site confers multiple benefits for human well-being, the decision context mediates their relative importance at multiple scales. This is important for understanding research potentials and limitations in influencing decision making at more local scales.

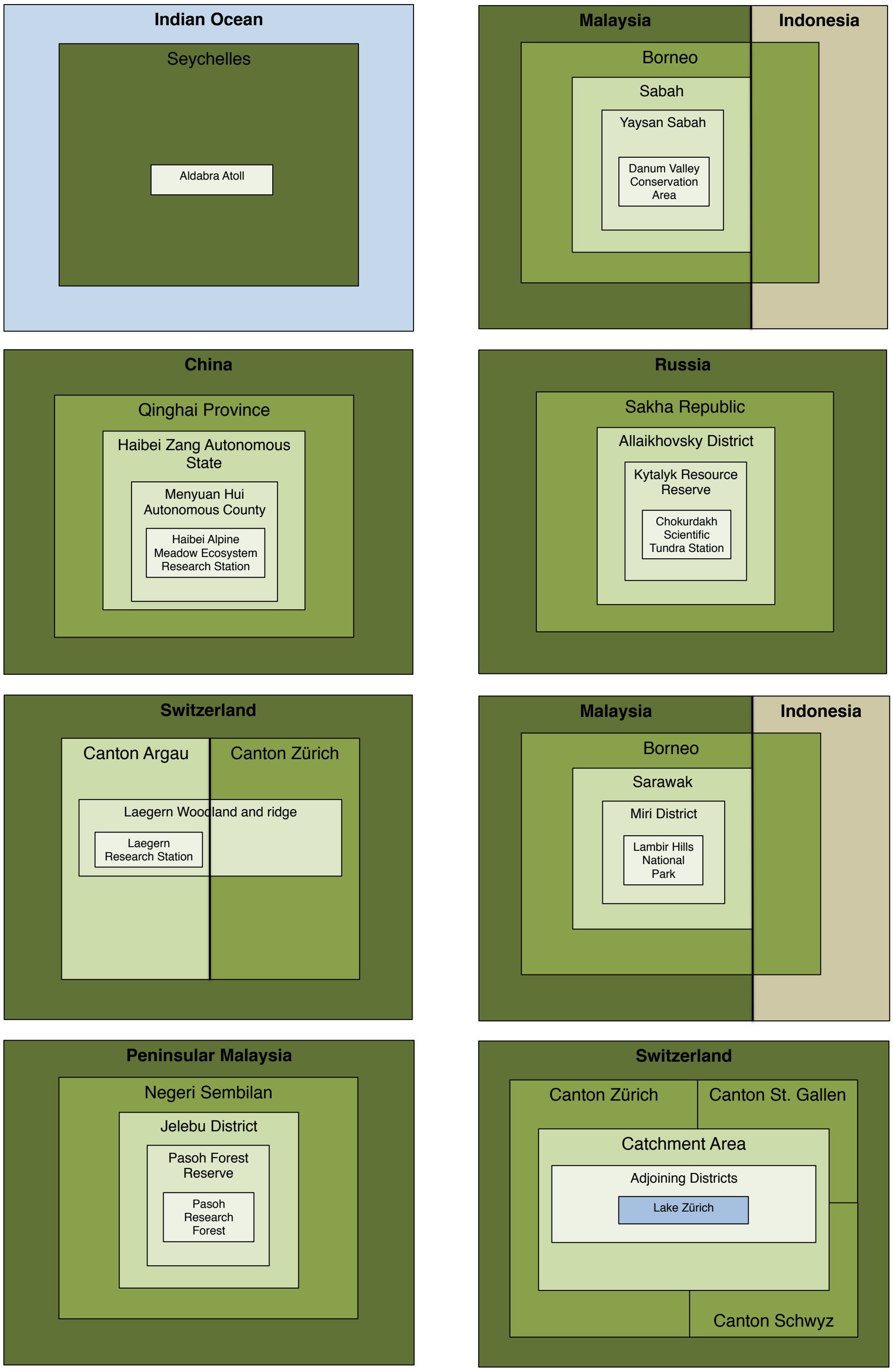

Figure 5: Generalised maps of the administrative contexts of each research site. e.g. Lambir Hills National Park is in the Miri District of Sarawak State in Malaysian Borneo, while Laegern research station is located in Laegern Forest, which is in two Cantons, Aargau and Zurich, in Switzerland

7.1 Aldabra Atoll, Republic of Seychelles

Tropical semi-humid atoll, 9.24S, 46.22E, elevation 6-8 m a.s.l.
Aldabra atoll is in the Indian Ocean, 1066km southwest of the main Seychelles island, Mahé, 420km northwest of Madagascar and 640km from the East African mainland. It is the second-largest raised coral atoll in the world, with a land area of 155.4 km^2, and is the main atoll in the Aldabra group of raised coral islands in the Seychelles archipelago. These consist of limestone formations on raised reefs that fringe deep sea mountain summits approximately 4000m high (Stoddart et al., 1971).

Four distinct islands form Aldabra Atoll - Grand Terre, Malabar, Picarde and Polymnie –surrounding a shallow lagoon. The lagoon covers an area of 196km^2, with about 40 smaller islands and rock outcrops within it. There are a few very small islets in the Western Channels. With a subtropical climate, there are distinct dry and wet seasons on Aldabra. The vegetation is a mosaic of open grassland, limestone *champignon,* and mixed and *Pemphis* scrub. Marine habitats include coral reefs, seagrass beds and mangrove mudflats edging the lagoon (UNESCO, 2018). Its distinct flora and fauna mean Aldabra has many key species, including the Aldabra giant tortoise (*Aldabrachelys gigantea*), Aldabra rail (*Dryolimnas cuvieri aldabranus*) and nesting green sea turtles (*Chelonia mydas*). All are recognized in its UNESCO World Heritage Site inscription (Seychelles Islands Foundation (SIF), 2012). Other bird species include the endemic Aldabra drongo (*Dicrurus aldabranus*) and a large colony of frigate birds (Lesser *Fregata ariel,* Greater *F. minor*). There are large colonies of coconut crab (*Birgus latro*), and important populations of black tip reef shark (*Carcharhinus melanopterus*) and dugongs (*Dugong dugon*).

The estimated population of the 155 island Republic of Seychelles, was 92,000 in 2014 (World Population Review, 2017) with the majority of people living on the main island, Mahé. Aldabra atoll itself has no permanent residents but there is a continually manned research base on Picarde, with a rotating total number of staff of 10-14 people. Tourist visits to the atoll are heavily restricted by limited access, high visit fees and no provision of accommodation (SIF, 2018).

Historically, habitation of Aldabra has been restricted by its difficult terrain, lack of water, and remote location in the Indian Ocean. These have consistently limited anthropogenic impacts and largely preserved intact terrestrial and marine ecosystems. This said, the atoll has seen human intervention and occupation over recent centuries, with some consequences for species and ecosystems. The atoll has probably long had a history with seafaring and piracy, and connections to Persian and Arabic mariners are reflected in its name: *Aldabra* translates to variants of *Al-*

Hadra or *Al-Khadra*, meaning either *green* (the reflection of the lagoon on clouds), or harsh (UNESCO, 2018). Remnants of drystone walls and water holes may relate back to this part of its history but there is not believed to have been any settlement before recent European occupations (Stoddart, 1971). The first known Europeans to visit the atoll were Portuguese navigators in 1511, and later in 1742 a French crew on a voyage that 'discovered' the Seychelles. There were subsequent visits throughout the next 80 years by French ships and local fishers, after the occupation and settlement of the wider Seychelles islands (Stoddart, 1971). In 1815, the Seychelles were given to the British and the atoll was administered and leased from 1888 to a number of different parties, for coconut plantations, mangrove extraction, and the harvesting and export of fish, tortoises and turtles (Seychelles Islands Foundation (SIF), 2012). The first settlement was built on Picarde at this time, with about 20 workers at the turn of the century (Stoddart, 1971). The lack of water largely led to the failure of the settlement of Aldabra in the longer term. After the Second World War, the population was limited to 200 people with the introduction of protection for the island fauna. By the 1950s the lease of Aldabra included a clause for South Island to be entirely protected. Jacques Cousteau, visiting in the same decade, was concerned about the atoll's future and tried to lease Aldabra himself to make it a wildlife sanctuary. He was unsuccessful but did much to raise public awareness in Europe. During the 1960s, there was pressure for the British colonial administration to hand the lease of Aldabra to the American Military to construct an airstrip and radio relay station. This led to successful protests from scientists from the Royal Society of London, and Seychellois. The lease was eventually handed to them in 1970, and in 1976 the island was handed over to the Seychelles.

From this time to the present, the atoll has been protected and the number of residents significantly reduced. After completion of their assigned work, the Royal Society left and the Seychelles Islands Foundation (SIF), a public trust, took over the management and protection of the atoll in 1979 (Seychelles Islands Foundation, 2018). SIF functions under the patronage of the President of Seychelles and Aldabra was declared a Special Nature Reserve in 1981. On 19 November 1982 it became a UNESCO World Heritage Site and is inscribed under three UNESCO criteria, all of which inform the long-term management of the atoll.

7.2 Danum Valley Conservation Area, Malaysian Borneo

Primary lowland dipterocarp forest, 5.09N, 117.64E, elevation 300-760m a.s.l.

Danum Valley Conservation Area (DVCA) is one of three fully protected forest areas in Sabah State, Malaysian Borneo, consisting 438km^2 of primary lowland rainforest within a wider tract of secondary forest (Reynolds et al., 2011).

The area is bounded by the Segama River on its eastern and southern edge, with a ridge defining the northern boundary. The land is rugged, with some areas of high ground (above 760m a.s.l.), steep slopes, other areas of undulating plateau, and a small area of flatter land. The soils are mixed and mostly basic. Rainfall is high but drier than other areas of northern Sabah, and influenced by the northeast and southwest monsoons (Sabah Forestry Department, 2005).

About 1300 plant species are known for DVCA, with species composition varying depending on soil type and elevation. It is broadly classified as a lowland mixed dipterocarp forest due to the predominance of the dipterocarpacaea. Fauna include about 275 bird species, all Bornean hornbills, about 124 mammal species and the 10 primate species found in eastern Sabah. Species of note include the orangutan (*Pongo borneo*), the Bornean pygmy elephant (*Elephas maximus borneensis*), sun bear, and clouded leopard (*Neofelis nebulosa*).

DVCA is uninhabited, while the population around it is sparse and the nearest large town, Lahad Datu, has a population of approximately 30,000 people with around 200,000 in the wider district (Department of Statistics, 2010). There are some settlements around the edge of the secondary forest, with people growing small cash crops. However, within DVCA, there is no evidence of any permanent settlements in the past despite the existence of some burial sites, although it is likely that people used the river to travel through the forest, even if they were not settled there (Hamza Tangki, pers. comm.). There has been a permanent field centre on the edge of the forest since 1986, with up to 100 staff and researchers there at any one time, along with other visitors. Tourist and school visits can increase this to around 300 in busy periods, as the centre has an active education outreach programme and the site is a popular destination for international tourists.

The British North Borneo Company administered Sabah for some time, and in 1984 the Forest Reserves Amendment Enactment led to the on paper designation of a lot of Forest Reserves. 48% of the land area of Sabah is now gazetted as Permanent Forest Reserve, with the Yayasan Sabah Foundation, a statutory body, holding a 100-year timber concession for 9730 km^2 of this area. DVCA falls within this and since 1995 has been managed as a Class 1 Forest Reserve, protected from logging for its high biodiversity value and is managed for conservation, research, and education purposes. It is considered to be an internationally important tropical forest research location (Sabah Forestry Department 2005; A. Hector et al. 2011).

7.3 Haibei Alpine Meadow Ecosystem Research Station, China

Alpine grassland, 37.48N, 101.21E, 4000m a.s.l.

The Haibei site is in Menyuan Hui Autonomous County in Haibei Autonomous Prefecture in Qinghai Province, China.

The Qinghai-Tibetan plateau is the source region of Asia's largest rivers, with a climate influenced by the Indian monsoon, within the Asian-Australian monsoon region (Hahn and Shukla, 1976; Zhisheng et al., 2001). The inland is dry and cold but the southeast is wet and humid, creating a large climate gradient. The southeast of the plateau region is largely forest with a transition zone between forest and grassland, which is about 70% grass. There are also low-growing shrubby areas (Xu and Liu, 2007). At high altitude there is low vegetation cover – the steppe - due to low temperatures and rainfall, strong winds, low nutrients, and prolonged snow cover (Ma et al., 2010; d'Alpoim Guedes et al., 2014). It is a sink for carbon stored in the permafrost, with very little release, although it risks becoming a source with permafrost degradation (Cheng and Wu, 2007; Genxu et al., 2008). The plateau system is fragile as it is hard for it to recover from disturbance due to the low cycling rates. There is consequently a strong influence of environmental change with a warming rate that is three times the global average, leading to increased grassland cover (Xu and Liu, 2007). The region has seen significant glacial retreat in the past 50 years (Yao et al., 2007). The degradation is also seen in changes in plant cover and in pika (*Ochotona dauurica, O. curzoniae*) mounds, a common species, often regarded as a pest species (Harris, 2010).

There are also impacts from increased human activities, specifically overgrazing as there is different regional pasture quality that changes the carrying capacity for sheep and cows. There is some fencing of degraded areas to prevent over-grazing but livestock are habituated to roaming freely. They consequently walk around the fences, increasing trampling causing further degradation (Zhao and Zhou, 1999; Li et al., 2008; Harris, 2010). The wider area around the Haibei research station provides freshwater for around 40% of the downstream population. As grassland moves upwards in the longer growing seasons due to climate warming, under careful management there is potential for increased productivity and shifts in areas used for grazing (Du, 2004). Human activities may also be able to have less-damaging impacts on such a sensitive system, with ecosystem restoration projects (Cai et al., 2015).

The fencing is a reflection of lifestyle changes, as families mark out their own pastures instead of using commons. This change is largely a result of government policy that aims to restrict and to settle nomadic and semi-nomadic people as a response to ecosystem degradation. The efficacy of this is not clear, and scientific findings are conflicting (Harris, 2010). There are also increases in mining, tourism, and urbanization.

Haibei station is owned and operated by the Northwest Institute of Plateau Biology, Chinese Academy of Sciences (DEIMS-SDR, 2018; NWIPB, 2018).

7.4 Chokurdakh Scientific Tundra Station, Kytalyk Resource Reserve, Russia

Arctic tundra, 70.82N, 147.47E; elevation 11 m a.s.l.
The north eastern Siberia site is located in the Kytalyk Resource Reserve in the Yana-Indigirka lowland in the Tundra subzone, inside the Arctic Circle (INTERACT, 2014). The State Nature Reserve – or Zakaznik (Sobolev et al., 1995; Krever et al., 2009) – was established and is named for the critically endangered and third rarest crane, the Siberian crane (*Leucogeranus leucogeranus)* (IUCN, 2015) by Sakha Republic and the Worldwide Fund for Nature (WWF) in 1996 and was extended in 1999. Alongside populations of Siberian crane, the reserve also has populations of wild reindeer (*Rangifer tarandus*, c.130,000) and significant populations of geese and sea birds including bean goose (*Anser fabalis rossicus*), white fronted goose (*Anser albifrons*), spectacled eider (*Somateria fischeri*), king eider (*Somateria spectabilis*) and Ross's gull (*Rhodostethia rosea*) (Beltrán and Phillips, 2000; SCWP, 2005).

The administrative centre – Chokurdakh – was founded in 1936 and has a population of 2367. This number is falling as people leave for bigger cities and opportunities. There are 3 communities of 'Indigenous' Even (the "Reindeer people") who engage in herding, hunting and fishing activities and who have been involved with the reserve establishment, an involvement which is considered unique within the establishment of Zakazniks (State Nature Reserves) (Beltrán and Phillips, 2000; Borrini-Feyerabend et al., 2007). These groups of people have a long migratory history and attempt to maintain their nomadic culture. However, collectivization under Soviet rule and conflicting post-Soviet policies with regard to indigenous groups have led to significant cultural and social change, including low mortality rates, uneven dispersal patterns and changes in education levels, identity, and language (Petrov, 2008). Soviet and post-Soviet policies saw the decline of traditional livelihoods, including fishing and reindeer herding (Xanthaki, 2004; Ksenofontov et al., 2017). The seaboard fishing industry has, in the past, partly supported people's livelihoods but also suffered serious decline, although current policy appears to support reviving the sector (Zeller et al., 2011; UNESCO_IOC, 2018). This despite the apparent low productivity of Sakha's coastal seas (Pauly and Swartz, 2007; UNESCO_IOC, 2018).

As a result of the establishment of specific management zones within the reserve, the Even communities inhabiting the area appear to obtain many benefits from the protected area. These include preserving valuable ecosystems and their associated wildlife, as well as ensuring the development and preservation of traditional cultural practices and other ecologically safe forms of natural resource use (Sirina, 2005). In 1991, with others, the republic of Sakha (Yakutia) adopted its own legislation regulating the rights of indigenous peoples and the utilisation of natural resources. Over the past decade, the indigenous peoples of Russia have begun to mobilise themselves into a political force. Following the 1990 Congress of Northern Ethnic Minorities (in which there were 16 Even among a total of 341 delegates), several public organisations of peoples of the north have been established. These include the Association of the Peoples of the North (APN), set up in 1990, the Deputy Assembly of minorities of the North, Siberia and the Far East (1991) and the International League of Minorities and Ethnic Groups (1991) (Beltrán and Phillips, 2000).

With the total 2010 population of Sakha Republic at 958,528 over a land area of 3,083,523 square kilometres (19% of the Russian Federation land surface and slightly larger than India) (The World Bank, 2015; Brinkhoff, 2017a; Encyclopaedia Britannica, 2018), the number of direct beneficiaries of these services is very low at local and regional scales. However, the direct and indirect benefits deriving from a functioning Arctic Tundra ecosystem are globally distributed. These include regulation of global climate patterns through methane sequestration in permafrost soils, freshwater locked in permafrost and seasonal freeze-thaw cycles, and carbon stored in frozen peat soils. Changing climate is predicted to have a high impact in Arctic regions, both ecologically and socio-economically (Whiteman et al., 2013; Pachauri et al., 2015).

The cultural importance of the traditional livelihoods is tightly linked to the importance of subsistence food gathering activities in the Kytalyk area, including gathering wild mushrooms and berries, fishing, and reindeer herding (Zhegusov et al., 2013; Ksenofontov et al., 2017). These are particularly important for people who live in and around the site, as seasonal subsistence level activities. The reserve area and the river system directly and indirectly provide water for multiple purposes, including drinking, to nomadic people but also to small settlements where it also passes through a water processing system.

7.5 Laegern Research Station, Switzerland

Temperate forest, 47.28.42N, 8.21.51.8E, elevation 700 m a.s.l.

Laegern is a mixed forest, on the on the south-facing slope of Laegern mountain, in the easternmost part of the Swiss Jura. It has considerable research infrastructure, including the CarboEurope forest flux site, EC Tower. The site is 20 km northwest of Zurich, with an altitudinal gradient of about 100 m and an average slope of 24° and extends 200m west and east and 150 m north and south of the EC Tower. Part of the forest is a nature reserve and comprises a mixed beech forest that has been unmanaged since 1998 alongside extensively managed forest under FSC (Forest Stewardship Council) guidelines. Site vegetation is typical for a highly diverse mixed temperate mountain forest. Generally, understory vegetation is scarce, consisting mostly of wild garlic (*Allium ursinum L.*), blackberry (*Rubus fruticosus*) and raspberry (*Rubus ideaus*) as well as juvenile beech (*Fagus sylvatica*) and ash (*Fraxinus excelsior*). The bedrock is mainly limestone, marl and sandstone, with transition zones between marl and limestone (loamy debris) and marl mixed with sandstone (loam) (Ruehr et al., 2010).

Laegern is located in the Swiss Cantons of Aargau and Zurich, with a local population of about 50,000 people from the nearby municipalities. It is important for recreation and forestry, with mostly farming communities around it. Laegern is administered by the forest divisions of the two Cantons and follows Forest Stewardship Council (FSC) guidelines for its timber management.

7.6 Lambir Hills National Park, Malaysian Borneo

Lowland tropical forest, 4.21N, 114.04E, elevation 150-465m a.s.l.

Lambir Hills National Park is located in Miri, the 4th Division of the state of Sarawak, Malaysian Borneo. The capital, Miri City, is about 30km to the north west of Lambir Hills. It was gazetted as a reserve for forest resources and biodiversity as well as for amenity, research and education in 1975 (Yamakura et al., 1995) and covers an area of 6952 ha. It consists of mixed tropical heath forest (keranga) and dipterocarp forest, with dipterocarp forest covering between 54% (Watson, 1985) and 85% (Yamakura et al., 1995) of the area. The topography is hilly with steep-sloped ridges and valleys. The underlying bedrock is a mix of clays, shales, fine- and coarse-grained sandstones and limited calcareous deposits. They are generally soft and can be poorly consolidated. Most soils are red-yellow podsols, which are generally low in nutrients (Yamakura et al., 1995). Lambir Hills is the watershed for four main river systems flowing north to Miri, southwest, southeast and east. The river flowing to Miri is the main water source for the city. The forest is considered to be one of the most plant species rich conserved forests in the world, with high endemism and several rare species (Watson, 1985; Yamakura et al., 1995; Lee et al., 2002; Harrison et al., 2013). Long-term research has been carried out in the Park since the 1950s (Watson, 1985).

While at its establishment the Park supported limited populations of several rare animal species, (sun bear *Helarctos malayanus*, sambar *Cervus unicolor*, langurs *Presbytis hosei*, Bornean gibbon *Hylobates muelleri*, hornbills *Aceros sp., Buceros sp., Anorrhinus galeritus*) (Watson, 1985), most of these seem to have almost entirely disappeared from Lambir Hills (Harrison, 2011; Harrison et al., 2013; Mohd-Azlan and Engkamat, 2006).

The closest large population to Lambir Hills is in Miri City, with a 2010 population of 300,543 and there are a number of smaller settlements around the National Park boundary (Sarawak Government, 2016). The population of Miri area is made up of ethnic Chinese, Malay, Bidayuh and Iban with the Iban comprising about 30% of the population (Ichikawa, 2006). These different groups have different relationships with and uses of the forest, with the Iban traditionally practicing shifting cultivation of rice paddy in the area (Ichikawa, 2006; Mertz et al., 2008). The extensive river system was how the Iban people initially visited and populated the area. They traditionally hunt forest mammals and would come into the forest for this, although didn't settle until the end of the nineteenth and beginning of the twentieth century (Ichikawa, 2006).

The park is owned by the Government of Sarawak and administered by the Forest Department. Day-to-day management is carried out by Sarawak Forestry, the operational arm of the Forest Department, which is itself a Government Agency. Broadly speaking, while the Forest Department is responsible for policy and legislation of all forests in Sarawak, Sarawak Forestry manage their own land holdings, such as Lambir Hills National Park (Forest Department, 2016).

7.7 Pasoh Forest Reserve, Peninsular Malaysia

Lowland Tropical Forest, 2.98N, 102.31E, elevation 75-150m a.s.l.

The Pasoh site is 13,900ha of logged, secondary and virgin forest. 1840ha are a protected forest reserve, where most of the staff and research effort is focused, consisting of 1240ha of secondary forest and 600ha (including a 50ha long-term research plot) of virgin forest. The reserve was established in 1969 by the Royal Society and the Smithsonian Institute, with Japanese Institutions becoming involved through the 1970s and '80s. Latterly there has also been involvement from Aberdeen University. Pasoh Forest Reserve is funded by the Forest Research Institute of Malaysia (FRIM), with some finance from these international research institutions (Fletcher et al., 2012; TEAM Network, 2018).

There is a small manual weather station and a weather tower with different equipment for the different research organisations, while the arboretum is used as a training area for foresters or other people wanting to learn about tree ID (Joann et al., 2012). Due to its long-established infrastructure, there are a large number of research projects carried out in Pasoh, ranging from tree demographics to soundscapes.

It is a highly diverse forest, with 814 species identified in the 50ha plot alone. There are some seasonal swamps in the reserve and three main soil types, wet alluvial, dry alluvial and hill soils. Vertebrates of note, although with limited sightings, include the black panther, tapir, sun bear, flat-headed cat, and the marbled cat (Fletcher et al., 2012; Forest Research Institute Malaysia, Various). It's possible that a lot of the wildlife in Pasoh is trapped, as it is an island of forest in the area surrounded by oil palm and rubber plantations with no corridors.

Around Pasoh forest, the indigenous Orang Asli (literally "original people") are the local people. Many are part of the large oil palm consortia that own the land around Pasoh. The Research Station tries to bridge between them, with some staff members who are themselves Orang Asli and projects with the plantation companies. However, there is also encroachment on the forest edge with some poaching activities. The staff sometimes catch poachers and traps, through good liaison between the Forestry and Wildlife Departments. Wildlife officers will patrol in areas where poachers are active.

7.8 Lake Zurich, Switzerland

Inland freshwater lake, 47.34N, 8.54E, elevation ~400m a.s.l.

Lake Zurich is an oligo-mesotrophic, peri-alpine lake located on the Swiss Plateau. There is a smaller upper lake and the two are well separated by a dam. The upstream section beyond the Rapperswil dam is the Obersee, and is shared between the cantons of St. Gallen and Schwyz (Oesch et al., 2006). The Linth river flows into Lake Zürich, and the Limmat emerges at the north western end of the lake. The maximum depth of Lake Zurich is 136m, and the surface area is approximately 88km^2. The lake mostly lies in the Canton of Zürich but a small portions of the eastern end lie in the Cantons of Schwyz, and St. Gallen (Encyclopaedia Britannica, 2012).

The eastern shores of the lake are characterized by the Schilt fields where flat bogs of national importance come together. These offer essential habitats for some rare and endangered species. Examples include grape weeds (*Gratiola officinalis*), curlew (*Numenius arquata*), the great reed warbler (*Acrocephalus arundinaceus*), and the great crested grebe (*Podiceps cristatus*). The shores also support reptiles and amphibians, and a wide variety of invertebrate species. The water body itself supports a number of fish species, including the arbor (*Alburnus alburnus*) (Oesch et al., 2006). Vines are grown on the northern banks, on south-facing slopes. Other agricultural uses of the shores of the lake include orchards and some livestock farming (Encyclopaedia Britannica, 2012).

This agricultural activity reflects the long history of human settlement on Lake Zürich, with evidence of Neolithic occupation and the early Roman development of what is now the old town (Ruoff, 2004; Doppler et al., 2017; Zurich Tourism, 2018; Stadt Zürich, 2018a). The shores of the lake are now almost completely occupied by urban development, with the city of Zürich located at the northern end. The population around lake Zurich numbers around 1 million people (Brinkhoff, 2017a; Stadt Zürich, 2018a).

With such a large population depending on it, primarily for drinking water, the lake is well regulated. Nutrient inputs are monitored, and regulated by the 25 sewage plants along its borders, water levels are modulated, and levels of cyanobacteria (*Planktothrix rubescens*) overseen. Over the last 40 years, the lake has experienced warming of the water column, with cyanobacteria becoming a consistent element in the microbial community(Kurmayer, 1999; Yankova et al., 2016).

Along with its importance for wildlife, history, and drinking water, the lake provides recreational opportunities for the people who live around it, from recreational fishing, to boat trips and swimming. There are many park areas along the lake shore within the city, which are fully accessible to the public. It is symbolic for the city of Zurich, whose history and culture is intrinsically bound up with the lake (Brinkhoff, 2017a; Stadt Zürich, 2018a, 2018b).

8 Position Statement

While I consider myself an outsider at all sites within this study, my experiences as a researcher, and formerly as a site ranger give me common experience and knowledge with most interviewees. I am aware, however, that studies undertaken by local or indigenous researchers may present different outputs to my own work here (Kahakalau, 2004). My values, norms and expectations as a UK citizen, employed by a Swiss Research Institute, are not the same for example, as those of locally employed research assistants or site managers.

This outside status can potentially create a lack of trust between interviewees, and myself if individuals are unsure of my position or my motives. It may also lead to a loss, or lack, of information, through mistrust or through linguistic differences. I am not a native speaker for any of the sites in this study (except Aldabra Atoll, where English, alongside Seychellois Creole and French, is an official language), which leads inevitably to linguistic simplification and loss of meaning, both in the questions being asked and the responses elicited. It also means that the time required to find and build trust with interviewees is greater than it might be for a local researcher.

However, there are some advantages of being an outsider for all locations. It has allowed me to be more objective in relation to the research sites. I have been able to formulate the same questions in the same way for every site, rather than developing a methodology that uses different questions depending on context (Kahakalau, 2004). This allows greater consistency across sites. As the interviewees for each site are not all local, and have mixed backgrounds, it would not be possible to design specific approaches for each site. As I have only interviewed people who are researchers or site managers, I have also been able to reduce the level of misunderstanding that might occur with a wider selection of stakeholders. I recognise that this biases the information gathered towards a group of people who either have site management experience and or scientific training. On the other hand, given the issues I have already outlined around trust building, this is an extremely useful starting point for considering the direction of further, more inclusive work at each site.

There is a risk that the outputs of this work could misrepresent the views of a wider community at each site. It is consequently important to state that the outputs should not be considered as a full and accurate representation of all actors at any one of the research locations.

Chapter 1

Expert Perceptions of the Presence and Importance of Ecosystem Services Across Diverse Research Sites

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Abstract

Ecosystem service assessments are widespread in environmental decision-making and management. The approach aims to define and quantify properties and functions of ecosystems, and biodiversity that are essential for human well-being, endeavouring to give values or weightings for these ecosystem services and the benefits they provide for people. There are many challenges, including how to produce accurate, quantitative measurements of ecosystem service supply and demand, predict changes in both aspects over time, and determine how supply and demand interact. While considerable effort is given to mapping, measuring and counting components of ecosystems, there is less focus on contextualising the system and eliciting information from experts at multiple levels. Fostering a willingness to codesign and coproduce research and its processes is essential, if researchers further aim to identify and integrate a more complete representation of beneficiaries in ecosystem services research (Primmer and Furman, 2012; Tengö et al., 2014, 2017). Structured interviews are one way to obtain an overview and more nuanced information about a given system and the multiple benefits it confers on the societies that depend on it. Multiple viewpoints provide essential preliminary information for environmental decision-makers wishing to implement credible, legitimate governance systems (Fisher et al., 2009; Geijzendorffer et al., 2017).

In this study, I used structured interviews with international and local experts to explore perceptions of the presence and importance of ecosystem services. The systems in the study are in a multidisciplinary research programme and globally distributed from northern Siberia to the Indian Ocean. The interviews revealed baseline information about perceptions of ecosystem service provision across and within those sites. I found that patterns of ecosystem service perceptions differ from site to site, but at each site the most similar perceptions are between ecosystem services from the same sections (cultural, provisioning, regulating). Ecosystem services group differently at each site, however, in cases where interviewees report high agreement about the presence of provisioning services, they tend to under-report on cultural services. I also show that experts are uncertain about the presence and the importance of some services at site level, in particular, regulating services. These can be hard to adequately measure and model, suggesting that interviews alone are not an effective method for assessing them. I also suggest that flexibility in definitions and indicators for ecosystem services is necessary to allow the multiple ecosystem properties and functions in different biomes to describe them. Finally, I find that cultural ecosystem services are indeed omnipresent and important.

1 Introduction

The field of ecosystem service research brings together experts from multiple research disciplines, policy perspectives, and knowledge systems to explore human interactions with and dependencies on nature. This multidisciplinary approach engenders creativity, innovation and collaboration in meeting the challenges of global change and sustainability (Carpenter et al., 2009; Seppelt et al., 2012; Schröter et al., 2014; Bennett et al., 2015; Kok et al., 2017).

From the outset, ecosystem service research has had to consider how to build consensus around terms and definitions that enable it to be inter- and transdisciplinary (de Groot et al., 2002; Abson et al., 2014; Alkemade et al., 2014). This continues to be a theme within the research community (Braat, 2018; Díaz et al., 2018; Masood, 2018; Nature, 2018; Peterson et al., 2018). This challenge has created a plethora of frameworks, including the Millennium Ecosystem Assessment (MA) (World Resources Institute, 2003), the ecosystem services cascade (Haines-Young and Potschin, 2010; La Notte et al., 2017), and the IPBES conceptual framework (World Resources Institute, 2003; Díaz et al., 2015b, 2015a; La Notte et al., 2017). There are multiple systems for classifying ecosystem services, for example The Economics of Ecosystems and Biodiversity (TEEB Synthesis, 2010), the Common International Classification of Ecosystem Services (CICES) (TEEB Synthesis, 2010; Haines-Young and Potschin, 2012; United Stated Environmental Protection Agency, 2015), Nature's Contributions to People (NCP) (Pascual et al., 2017a), or the National Ecosystem Services Classification System (NESCS) (United Stated Environmental Protection Agency, 2015). To operationalize these frameworks and typologies, a number of approaches and methods have been posited (Crossman et al., 2013; Mace et al., 2015; Rabe et al., 2016), with tools designed for their implementation (Sherrouse et al., 2011; Jacobs et al., 2014; Peh et al., 2014; "Co$ting Nature," 2018; Natural Capital Project, n.d.). Researchers are consequently faced with the challenge of selecting the frameworks, classifications and tools that best support investigation of their specific research questions, as are decision makers at an applied level (Burkhard et al., 2014).

The multiplicity of approaches has in turn created a heterogeneous mix of indicators that can be variably employed to measure ecosystem services (Egoh et al., 2012; Bastian, 2013; Tittensor et al., 2014; Kearney et al., 2017). For example, waste mediation may be indicated by dust filtration from urban trees, or by salt marshes trapping particles in roots (Haines-Young and Potschin, 2018), depending on the question being in asked and the system it is asked in (Gómez-Baggethun et al., 2010). There is the added challenge of combining these ecological variables with social ones, such as 'the biophysical characteristics or qualities of species or ecosystems that contribute to cultural heritage' (Haines-Young and Potschin, 2018). Defining what these 'qualities' might be, what cultural heritage is and how this might contribute to 'quality of life', as pointed out by Zorondo-Rodríguez et al., might not be commensurate with indicators currently used for defining quality of life (Zorondo-Rodríguez et al., 2014; Sterling et al., 2017)services Assessing whether indicators are meaningful seems to be possible with services that are more easily quantifiable , such as provisioning and regulating services (Worm et al., 2006; Mononen et al., 2016; Rabe et al., 2016), although this is complicated by the need to understand the scale, stocks and flows of functions (Fisher et al., 2009; Mitchell et al., 2013; Oliver et al., 2015). That is, how much is there and where? How are ecosystem services flows distributed across spaceand time?

Problems inherent in defining stocks, flows and status of system specific services, are further complicated when we try to describe the synergies and trade-offs between them, at multiple spatial and temporal scales (Butler et al., 2013; Cavender-Bares et al., 2015). An analysis of trade-offs is however necessary for priority setting in resource planning (Nelson et al., 2009; Reed et al., 2013), helping to spatially identify areas of conflict (or lose-lose), and those areas where synergies can be maximised (win-win) (Howe et al., 2014). Studies have highlighted that conflicts commonly occur between provisioning and other services (Fisher et al., 2011; Duncker et al., 2012; Howe et al., 2014).

One approach that aims to have a broader understanding of the spatial scale of ecosystem service trade-offs and synergies, is to aggregate services into spatially explicit bundles (Lamarque et al., 2014). This can highlight spatially differentiated patterns of services within diverse ecosystems, and reveal common associations between services.

Both of these approaches, trade-offs and bundles – are possible to apply not only to ecological but also to social systems (Dee et al., 2017). Synergies and Trade-offs in services inherently involve synergies and trade-offs between people - groups of beneficiaries (Butler et al., 2013). It is also possible to bundle not only services, but also human preferences (Klain et al., 2014) and socio-ecological networks to better understand how people are connected in a landscape. Awareness of preferences, of winners and losers, and power relationships, is essential for resource managers and decision makers wishing to avoid and or mitigate conflict (Adams et al., 2014). As important as understanding the ecological impacts of spatial and temporal changes in resource management (Pascual et al., 2017b).

However, connecting winners, losers and people's preferences in biophysical systems is problematic, particularly as most ecosystem services research effort has been given to supply (biodiversity, ecosystem functioning and ecosystem service mapping) (Martínez-Harms and Balvanera, 2012; Crossman et al., 2013). Work that considers demand (how to include beneficiaries) lags behind (Burkhard et al., 2014; Haase et al., 2014). Consequently, confusion can exist around the distinction between ecosystem services and ecosystem functions (Worm et al., 2006; Seppelt et al., 2011; Huntington, 2013). Functions need to be connected to people (beneficiaries) to become services (Manning et al., 2018). These beneficiaries are place based and need to be defined with different socio-cultural identies and their multiple dependencies on the system (Kremen, 2005; Fisher et al., 2009; De Vreese et al., 2016) for ecosystem service assessments to be fully representative of each system.

This challenge brings cultural services to the fore, services that remain a challenge to quantify and integrate with measures (or values) for provisioning and regulating services (Chan et al., 2012a; Daniel et al., 2012). More research, largely informed by the sustainability and social-ecological systems (SES) communities (Ostrom, 2009), is untangling how we think about cultural services, and the types of values that are assigned both to these services and to ecosystems at large. That cultural services are implicit in many provisioning and regulating services (Huntington, 2013; Díaz et al., 2018), or 'everywhere', as posited by (Chan et al., 2016), is helping to frame new ways of thinking about what and where they are, and to whom.

Despite this intricate mosaic of research challenges, the diversity within the ecosystem services field facilitates flexibility, and this is an advantage (Costanza, 2008). Across biomes, at multiple spatial and temporal scales, it is possible to make a start at meaningful, integrated ecosystem service assessments. While diversity reflects differences in perceptions of ecosystem services
, it also highlights the need to find ways towards consensus, driven by the growing political relevance of platforms such as the Convention on Biological Diversity (CBD), the Sustainable Development Goals (SDGs) and IPBES (Geijzendorffer et al., 2017; Pascual et al., 2017b). This in itself is a reflection of a continuing willingness in many disciplines, and from multiple experts and knowledge holders, to engage in the process of tackling the wicked problems of how to live equitably and sustainably on our planet (Berbés-Blázquez et al., 2016; Folke et al., 2016).

Taking the issues outlined above into account, in this study I take one set of definitions (CICES V4), apply them across multiple biomes (arctic tundra, alpine grassland, tropical forest, coral atoll, inland freshwater, and temperate forest), at specific research sites (protected areas and research stations), and use structured interviews with experts (research scientists, site managers, site officers) to elicit perceptions (qualitative information) of the presence and importance of ecosystem services.

I expected to find uncertainty around definitions, and more uncertaintiy with recgultaing than other services., and this comes out most strongly with regulating services, while cultural services are ubiquitous but described differently at each site. When analysing patterns of perceptions, the perceived presence or absence of provisioning services is most often negatively related to the perceived presence or absence of cultural, and some regulating, services. I also find site specific ‘bundles’ of perceptions of ecosystem services that cannot be aggregated at a larger scale. Flexibility allows interviewees to describe less tangible services in multiple ways, possibly creating ‘fuzzy’ definitions but also capturing information that would be missed within more rigid framings.

2. Methods

2.1 Site Selection

The sites used for this study are all research areas included in the University of Zurich Research Priority Programme Global Change and Biodiversity (URPP GCB). They were selected as a suite of globally distinct ecosystems at different latitudes, covering a range of biomes and representing a diversity of species, habitats, and systems. Differences between the sites include size, vegetation type, local climate, elevation, population size, land use and socio-political conditions. Human societies derive different benefits from each site at different scales. The eight sites included in this study are:

Aldabra

Aldabra Atoll (9.24S, 46.22E, 6-8 m a.s.l.), an island in the Republic of Seychelles, is located in the southwest Indian Ocean 420 km northwest of Madagascar and 640 km from the East African mainland. It is the second-largest raised coral atoll in the world, with a land area of 155.4km^2 and an inner lagoon covering196 km^2. It is the main atoll in the Aldabra group of raised coral islands in the Seychelles archipelago. These consist of limestone formations on raised reefs that fringe deep sea mountain summits approximately 4000m high (Beamish, 1970; Stoddart et al., 1971; Walton, 2014). Due to its unique flora and fauna and near pristine condition, it is designated as a UNESCO World Heritage Site (UNESCO, 2018). The atoll is largely inaccessible to visitors and has no permanent residents. It has a continually manned research base, maintaining a small population of site rangers, researchers and technical staff of up to 20 people. The wider population of the 155 island Republic of Seychelles, is an estimated 95,000 (World Population Review, 2017).

Danum

Danum Valley Conservation Area (DVCA) is an area of lowland mixed dipterocarp forest with tracts of upland forest, located in Sabah, Malaysian Borneo (5.09N, 117.64E, 120-917m a.s.l.). The primary forest covers an area of 438km^2 within a wider tract of secondary forest, managed by the Yayasan Sabah Foundation (Reynolds et al., 2011). DVCA is a Class 1 (Protection) Forest Reserve, protected from logging for its high biodiversity value and is managed for conservation, research, and education purposes (Marsh and Greer, 1992). It has an estimated 1300 species of higher plants, of which dipterocarps make-up about 88% of the total volume. The forest is a refuge for a rich fauna, with around 275 bird species, including all Bornean hornbills (*Bucerotidae*), and about 124 mammal species.

Among these are 10 primate species, including the Bornean orangutan (*Pongo borneo*), and populations of the Bornean pygmy elephant (*Elephas maximus borneensis*). There is also a very high but less well-documented invertebrate fauna (Edwards et al., 2014; Sabah Forestry Department, 2005). The permanent field centre is located on the edge of the forest and accommodates up to around 80 field staff and researchers there at any one time. Tourist and school visits can increase this to around 200 in busy periods. The population around DVCA is sparse and the nearest large town, Lahad Datu, has a population of approximately 30,000 people (Department of Statistics, 2010).

Haibei

The Haibei Alpine Meadow Ecosystem Research Station (HAMERS) is located on the Tibetan Plateau in Haibei Autonomous Prefecture in Qinghai Province, China (37.48N, 101.21E, 2900-3500m a.s.l.) (DEIMS-SDR, 2018; NWIPB, 2018). While the research station is just 0.06ha, the Tibetan Plateau ecosystem is in the region of 2500000km^2 (Liu et al., 2006), with Haibei Prefecture making up 39354km^2 of this area (Wikipedia, 2017) . The plateau system experiences short summers with high rainfall and longer very cold winters. It is alpine meadow, dominated by sedges and grasses with some shrubby species, and is used as summer grazing land for domesticated Tibetan sheep (*Ovis sp.*) and yaks (*Bos grunniens*) (Li et al., 2007). The research station has a fluctuating population of around 40 researchers, while the population of Haibei Prefecture is approximately 297000 inhabitants (CEIC, 2015), although the area is not easily accessible.

Kytalyk

The north eastern Siberia research site, Chokurdakh Scientific Tundra Station, is in Kytalyk Resource Reserve in the Yana-Indigirka lowland of the tundra subzone (70.82N, 147.47E, 11 m a.s.l.) and is located inside the Arctic Circle, about 25km north of Chokurdakh (INTERACT, 2014). The reserve has an area of 16,080km^2, within the 1233400km^2 of Sakha Republic. The population of this region is approximately 960000 inhabitants (East Asian-Australasian Flyway Partnership, 2018; Encyclopaedia Britannica, 2018). Kytalyk is a State Nature Reserve, or Zakaznik and was established and named for the critically endangered Siberian crane (*Leucogeranus leucogeranus*) (IUCN, 2015) by local indigenous groups, Sakha Republic and the Worldwide Fund for Nature (WWF) in 1996 (Sobolev et al., 1995; Krever et al., 2009). The reserve also has populations of wild reindeer (*Rangifer tarandus*) and significant populations of geese and other migratory birds (Beltrán and Phillips, 2000; SCWP, 2005). There are three communities of Even people with a long migratory history who endeavour to maintain their nomadic culture (Beltrán and Phillips, 2000; Borrini-Feyerabend et al., 2007).

Laegern

The Laegern Research Station is located in a Swiss temperate mixed forest (47.28.42N, 8.21.51.8E, 408-859 m a.s.l.) on the Laegern ridge of the Jura mountains (Schneider et al., 2017). It is approximately 20km northwest of the city of Zürich and has shared management between the Cantons of Aargau and Zurich (Bürgi et al., 2010; Schneider et al., 2017). The research site has an area of approximately nine hectares around the CarboEurope forest flux tower, while the wider forest site is 400ha. Laegern is mixed beech forest extensively managed under FSC (Forest Stewardship Council) guidelines, with a reserve area that has been unmanaged since 1998 (Braun, 2017; University of Zurich, 2017). Site vegetation is typical for a highly diverse mixed temperate mountain forest. (Ruehr et al., 2010). The population of the municipalities around Laegern is approximately 48000 inhabitants, although population living within an hour of the area is closer to around one million inhabitants (Stadt Zürich, 2018a).

Lambir

Lambir Hills National Park is a state run forest in Sarawak, Malaysian Borneo (4.21N, 114.04E, 150-465m a.s.l.), about 30km from Miri City. It covers an area of 6952 ha and is managed by Sarawak Forestry. The forest was established on the central portion of the Lambir Hills, a sandstone escarpment, and was gazetted as a reserve for forest resources, biodiversity, amenity, research and education in 1975 (Yamakura et al., 1995). The forest area consists of mixed tropical heath forest (keranga) and dipterocarp forest (Watson, 1985; Yamakura et al., 1995). It is the watershed for four main river systems and is considered to be one of the most plant species rich conserved forests in the world, with high endemism and several rare species (Harrison et al., 2013; Lee et al., 2002; Smithsonian Tropical Research Institute, 2018; Watson, 1985). Long-term research has been carried out in the Park since the 1950s (Watson, 1985). The population of Miri District is approximately 365,000 (Sarawak Government, 2016) with a number of smaller settlements around the National Park boundary.

Pasoh

Pasoh Forest Reserve is located approximately 70km south of Kuala Lumpur on Peninsular Malaysia (2.98N, 102.31E, 75-600m a.s.l.). It is a largely lowland dipterocarp forest with a total area of approximately 140km^2. Within the reserve there is a 600ha core area of virgin rainforest within a larger 1840ha tract that has been previously logged. This 1840ha area has been managed as research forest since 1977 by the State Forestry Department of Negeri Sembilan (Fletcher et al., 2012). There are 814 tree species, including sandalwood (*Santalam spp.)*, dipterocarps, and a number of fruit bearing species (Joann et al., 2012; TEAM Network, 2018). The forest has a high diversity of birds, invertebrates, mammals and primates, including sun bear (*Helarctos malayanus*), flat-headed (*Prionailurus planiceps*) and marbled cats (*Pardofelis marmorata*), and the white-handed gibbon (*Hylobates lar*) (TEAM Network, 2018). The forest is potentially accessible to a large number of people, as it is surrounded by a number of towns and villages. The population of the local district, Jelebu, is around 40,000 people (Brinkhoff, 2017b) and that of Negeri Sembilan State is approximately 1.11 million inhabitants (Department of Statistics, Malaysia, 2018).

Zurich

Lake Zurich (47.34N, 8.54E, 404m a.s.l.) is on the border between the midland and the pre-alpine region of Switzerland. It has a surface area of about 88km^2, with a width of between 2.5 and 0.5km, and a total length of 40km (Oesch et al., 2006; Stadt Zürich, 2018c). Its inflow is from lake Obersee at the south-eastern end where it is dammed, and the lake flows out to form the river Limmat to the north, in the city of Zurich. It has a maximum depth of 406m. It is a freshwater lake, supporting populations of amphibians and reptiles, invertebrate and fish species. The south eastern shore and inflow area are important reedbed habitat and the lake also supports bird populations including common tern and reed warblers. The lake waters are very clean, providing 70% of Zurich's drinking water (Stadt Zürich, 2018b). The lake is very accessible to a large number of people and the populations of the districts along the borders of the lake total about 754200 inhabitants (Stadt Zürich, 2018a). For the agglomeration of the Zurich area, the largest in Switzerland, it is 1.35 million people (Brinkhoff, 2017a).

2.2 Interviewee Selection

In order to be sure that I had permission to carry out interviews, my interviewee selection was very simple. I used snowball sampling, beginning with URPP GCB affiliated researchers at each site and extending to other staff and researchers involved with the various sites. Given the substantial spatial scope of this study (reaching across 8 sites), I was unable to obtain the necessary permissions needed to interview local residents not associated with the sites. Although a number of the site employees interviewed were also local residents.

This specific selection of experts is important in understanding the knowledge and motivations of those stakeholders who have a direct influence on aspects of how the Protected Areas and research sites are managed and externally presented. While this necessarily entails excluding other beneficiaries, it nevertheless reveals perceptions that might not initially be apparent if the 'expert' role of the interviewee is taken for granted. It is also possible to learn where different experts have different priorities, and where research needs and research activities do not align.

2.3 Questionnaire Design

I used the Common International Classification of Ecosystem Services (CICES V4.3, example in Appendix 1) to define 48 ecosystem service classes in three sections (cultural, provisioning, regulating). CICES includes more detailed descriptions for each class in the notes for division, group and class type which I used as guides for formulating site specific examples, where necessary. This classification was already being used within the URPP GCB to align with the Essential Biodiversity Variables (EBVs), and underpins work undertaken by, for example, Action 5 of the EU Biodiversity Strategy (Maes et al., 2013).

I formulated pilot questionnaires (Appendix 2) around the 48 classes, asking a small number of URPP GCB researchers whether they thought each service was present at a specific site, and how important they felt it was. I used their responses to determine how far expert interviewees understood the ecosystem services concept. I also elicited some preliminary perceptions of which services are present and important at the research sites. The pilot indicated a number of issues:

- some researchers were unfamiliar with the concept of ecosystem services
- I needed to be clear about specific definitions of ecosystem services at research sites. For example, what does bioremediation mean in each location? On Aldabra, while it makes sense that mangroves might be included in this service, remediation in this context refers to nutrient cycling rather than specifically removing pollutants and toxins from the system.
- it was difficult to be precise about which aspects of the system were being discussed and I needed to have examples ready without biasing responses.
- Although researchers had visited the site and understood some aspects of ecosystem functioning, many were unclear about context. This might be site

designation, which organisations were responsible for the sites, types of visitor to sites and the wider cultural importance of sites.

With these points in mind, I spent some time researching each site and formulating examples for services that could be more easily understood. I reformulated questions, as far as possible removing ecosystem services specific jargon. I kept the CICES definitions alongside them to be clear about which class each question referred to. I combined some services into one question, for example, pest control and disease control were both included in question 23, *"Do you think there are more or less pests and diseases in this area than in other places, for example in the city?"* The decision to combine classes was based on responses where interviewees frequently replied that the response was the same for each class. Finally I had the questionnaires professionally translated into German, Chinese and Russian for use with interviewees at the Swiss sites, Haibei and Kytalyk. Native speaker colleagues who were familiar with my study then checked the translations for accuracy. The English version of the final questionnaire is shown in Appendix 2.

2.4 Interview Procedure and Data Collection

I conducted 103 interviews in total across the eight research sites with researchers, site managers and site staff. With 48 ecosystem services this gave a potential total of 4944 data points.

Prior to each interview, I confirmed that interviewees consented to take part in the study and that personal data would be anonymous (see Site Visit Protocol, Appendix 3). For each question, I again asked interviewees whether they thought the service (or ecosystem function described in the question) was provided by the research area and how important it was. For example, *"Do you think this area helps to prevent flooding?"*. I recorded responses regarding the presence or absence of services with *yes*, *no* or *don't know*, and with *low*, *medium* or *high* importance. These scores gave the presence and importance data used in the following analyses. There were 103 interviews in total across the eight research sites. With 48 ecosystem services this gave a potential total of 4944 data points.

In some cases, I needed a translator to work with me, specifically for a few interviewees for the Swiss (German speaking) sites, and for Chinese speakers in Haibei. The principle investigators for the Kytalyk and Haibei sites gave the questionnaires to some interviewees to complete in writing (1 and 33 respectively), and five interviews at Haibei were conducted face-to-face by a Chinese colleague, who noted their answers. I conducted all other interviews in person, most of which were taken as written notes but I recorded a small number and later transcribed them. The interviews that were written in Chinese were translated for me by two colleagues, while I was able to translate the one in Russian. I was present at all interviews conducted in Swiss German where I took notes in English and a colleague did the same in German. I was able to translate her written answers with her assistance.

2.5 Data Reliability

To test whether a sufficient number of interviewees had been interviewed to capture information about ecosystem services at the research sites, I performed randomised accumulation curves (data added randomly, 500 permutations) for each set of site responses using the Vegan package in R (R Studio version 1.0.136, package 2.4-1). Curves that flatten and or approach the maximum possible number of ecosystem services (48) were assumed to indicate that adding more interviewees would not increase the number of services for the site (Gotelli and Colwell, 2011). Other work using structured interviews indicates that at around 20-30 interviewees there is a reduced amount of extra information obtained (Klain et al., 2014). In this analysis I found that after around 8 interviewees, no new ecosystem services were added for individual sites. Consequently here, three sites have more than this maximum and the full dataset has a more than adequate amount of interviews. These tests were performed after all other analyses.

2.6 Presence, Uncertainty and Importance

I used the coarse presence dataset to indicate which services were or were not perceived to be present at the research sites, with varying levels of certainty. Mean site scores for each ecosystem service were used to indicate whether overall that service is perceived to be present or absent (figure 1). Mean scores below 0.35 indicate non-presence of the service (less than half of interviewees said ‘no’), and scores above 0.65 (more than half of interviewees said ‘yes’) were taken to indicate the presence of the service. Scores falling between these values indicate uncertainty amongst interviewees about the presence or absence of the service at the research site. Uncertainty scores reflect that some interviewees perceived a service as present (1) and others perceived that it was absent (0). 0.35-0.65 were chosen as the lower and upper boundaries to indicate uncertainty based on the numbers of interviewees for each site and to be sure that a sufficiently low or high number of interviewees were captured to indicate certain presence/absence. The choice of these boundaries ensured even numbers of interviewees for presence/absence scores. Expanding the limits to 0.33-0.667 would have given a wider range of uncertainty for the one site with 6 interviewees (see table 1).

n interviewees	n interviewees for absence	% interviewees for absence	n interviewees for presence	% interviewees for absence
5	0-1	0-0.2	4-5	0.8-1
6	0-2	0-0.333	4-6	0.667-1
7	0-2	0-0.286	5-7	0.714-1
8	0-2	0-0.25	6-8	0.75-1

Table 1: Numbers of interviewees with percentage of responses this represents when 0.35-0.65 boundaries are applied for uncertainty.

I used the importance scores given for ecosystem services across the sites to assess which, if any, services were globally perceived as important. The services agreed to be present were scored from 1 (low importance) to 3 (high importance). The arithmetic means of this importance data were used to score perceived importance at each site. Scores of 2 or more were assumed to indicate high importance and scores below 1.5 indicate low importance.

The presence data were used to search for any services that were perceived to be present at only one or two sites, while means of importance scores were used to illustrate the services at each site that interviewees considered to be the most important. The same methods for looking at presence and importance were also used to look for services that were both present and important at individual sites.

2.7 Similarity and Difference

To investigate whether importance scores for ecosystem services are interdependent across and within sites, I calculated correlation coefficients and plotted correlation matrices using r package corrplot version 0.77. Method used was Pearson and matrices were plotted on the angular order of Eigen vectors.

To calculate the full data matrix across the sites I aggregated the data. Within sites no aggregations was necessary. I used correlation coefficient thresholds of ±0.75 to indicate positive and negative correlations. Although a coefficient of ±0.5 can be sufficient to indicate strong relationships between variables, I raised the threshold in order to better focus on the strongest correlations from a dataset of 1128. I also wanted to be clear that the relationships were reliable in a dataset that in some cases has a limited number of data points, particularly within sites. As correlation coefficients indicate the possibility of knowing the value (presence) of service b if you know about the presence of service a, by choosing coefficient values of +-0.75, I had a 3 in 4 chance of accurately predicting service presence based on another service. Coefficients between these thresholds were considered to be uncorrelated, although it is possible that ±0.5 suggests some relatedness between service perceptions.

To test these patterns statistically, I performed mantel tests on the correlation matrices to compare the correlation matrix of one site to that of another site. This tests how similar the patterns of correlations (the similarity and difference in perceptions about all possible pairs of ecosystem services) at two different sites are. This shows whether the site affects how people perceive ecosystem services and the connections between them. By randomly reassigning the data multiple times, I could see whether the observed data at each site is distributed by chance or is in fact specific to that site. The mantel statistic used is based on Pearson's product-moment correlation. A low test statistic (r) implies weak correlations between matrices. I used qgraph (v1.4.4) to plot networks of the correlation matrices.

2.8 Terminology

Throughout the text, I use the terms *research area, site* and *ecosystem*. *Research area* refers to the specific location where research is carried out and may not include the wider reserve or ecosystem. *Site* refers to the reserve or protected area within which the research takes place but may be wider than just the research location. For example, researchers at Laegern forest use either a nine hectare or 400x400m plot for their work, but this is situated within the boundaries of the forest site, which is 400 hectares. *Ecosystem* refers to the landscape scale of each system. For example, Chokurdakh research station is a very small research area located within the 16,000km^2 Kytalyk Resource Reserve, and these are both located within the vast arctic tundra ecosystem (Russian tundra area is approximately 1710million hectares). This scaling of terms is dependent both on interviewee responses and on the characteristics of the ecosystem service described.

3. Results

A total of 103 interviews were carried out across eight research sites. There were 42 interviews for Haibei, 17 for Aldabra, 11 at Laegern, eight at Danum, seven for Kytalyk and Pasoh, six for Lambir Hills, and five for Lake Zurich. The numbers of services identified were initially counted as any instance of an interviewee scoring 1 for presence (table 2: Total, and represented in figure 2 below). These responses were modified depending on the mean score from all interviewees per site for that service (table 1 and see section 3.2.1, and figures 3 and 4 below). Before standardising to mean scores, across the full dataset all 48 services are perceived to be present (as shown in figure 1). After standardisation, this is reduced to 43 services. The five that are excluded are 16, 17 (both related to aquaculture), 27 (animal based energy), 37 (storm protection) and 46 (chemical condition of salt waters).

Site	Total ES	Standardised ES	Site	Total ES	Standardised ES
Aldabra	44	22	Laegern	46	28
Danum	45	33	Lambir	45	34
Haibei	46	27	Pasoh	45	22
Kytalyk	40	24	Zurich	43	27

Table 2: Total numbers of reported ecosystem services (ES) and numbers after standardisation across responses.

3.1 Data Reliability

The accumulation curve for the number of services reported across all sites with number of interviewees (figure 1) begins to saturate (i.e. reaches a slope of less than 0.3) with data from approximately seven interviewees. At this point, an average of over 45 of the 48 ecosystem services were recorded as present. With nine interviewees, the slope is less than 0.2 and number of services increased by one or two. Twelve to 14 interviewees gives a slope of less than 0.1 (n= 46.79, sd=0.934) and again an increase of one or two reported services. To be sure that I could reach the full number of ecosystem services (48) across all sites, I would have needed 80-90 interviewees.

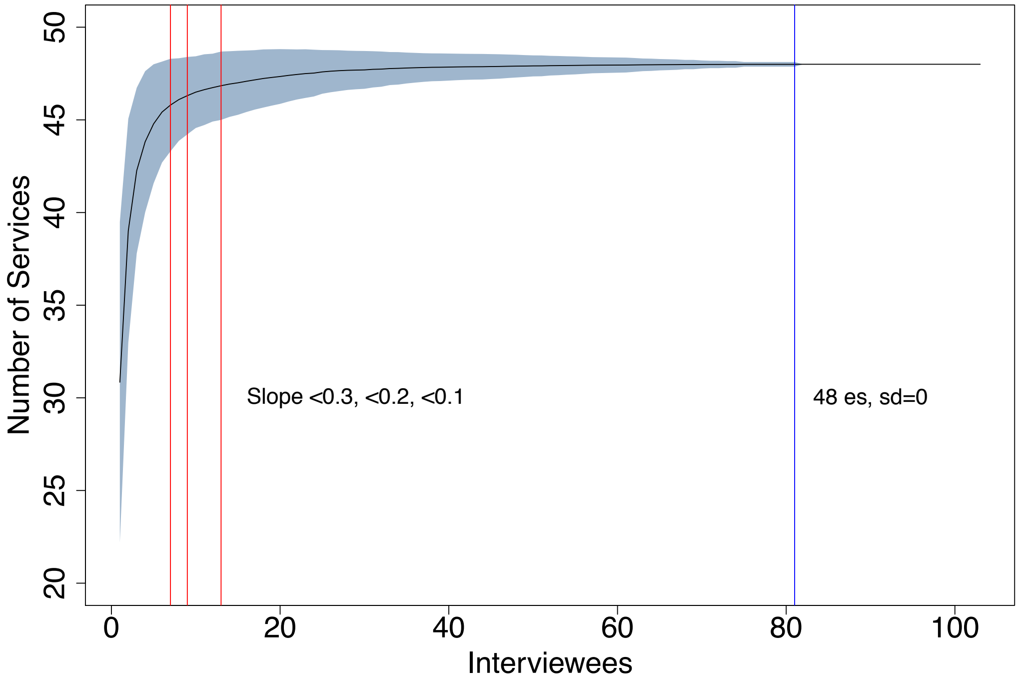

Figure 1: Accumulation curve for the full data set. Full number of ecosystem services = 48, number of interviewees = 103. Red vertical lines indicate where the curve reaches slopes of less than 0.3, 0.2 and 0.1. At 0.3, 7 interviewees are needed; at 0.2, 9 are needed; and at 0.1, 13 are needed.

When focusing on individual site data, the three sites with more than eight interviewees (Aldabra, Haibei, Laegern) achieve slopes of less than 0.3, indicating that the number of services reported is saturating (figure 2). Aldabra requires 10-11 interviewees, Haibei six to seven, and Laegern needs six for this amount of saturation. Danum Valley, with eight interviewees does not saturate and only reaches a slope of 0.54 with seven interviewees. Pasoh, with a total of seven interviewees, needs six for a slope of less than 0.3. The remaining three sites (Kytalyk, Lambir Hills and Lake Zurich) do not reach a slope of 0.3, and therefore are not approaching saturation given the number of interviews conducted.

I carried out the following, more detailed analyses on the full data set and on the four sites with eight or more interviewees (Aldabra, Danum, Haibei and Laegern). However, the outputs from the accumulation curves suggest that any analysis for the Danum site should be treated with caution, as it is possible that I did not interview a sufficient number of people for representative results. In addition, the data collected from the Pasoh site could be included in further analysis.

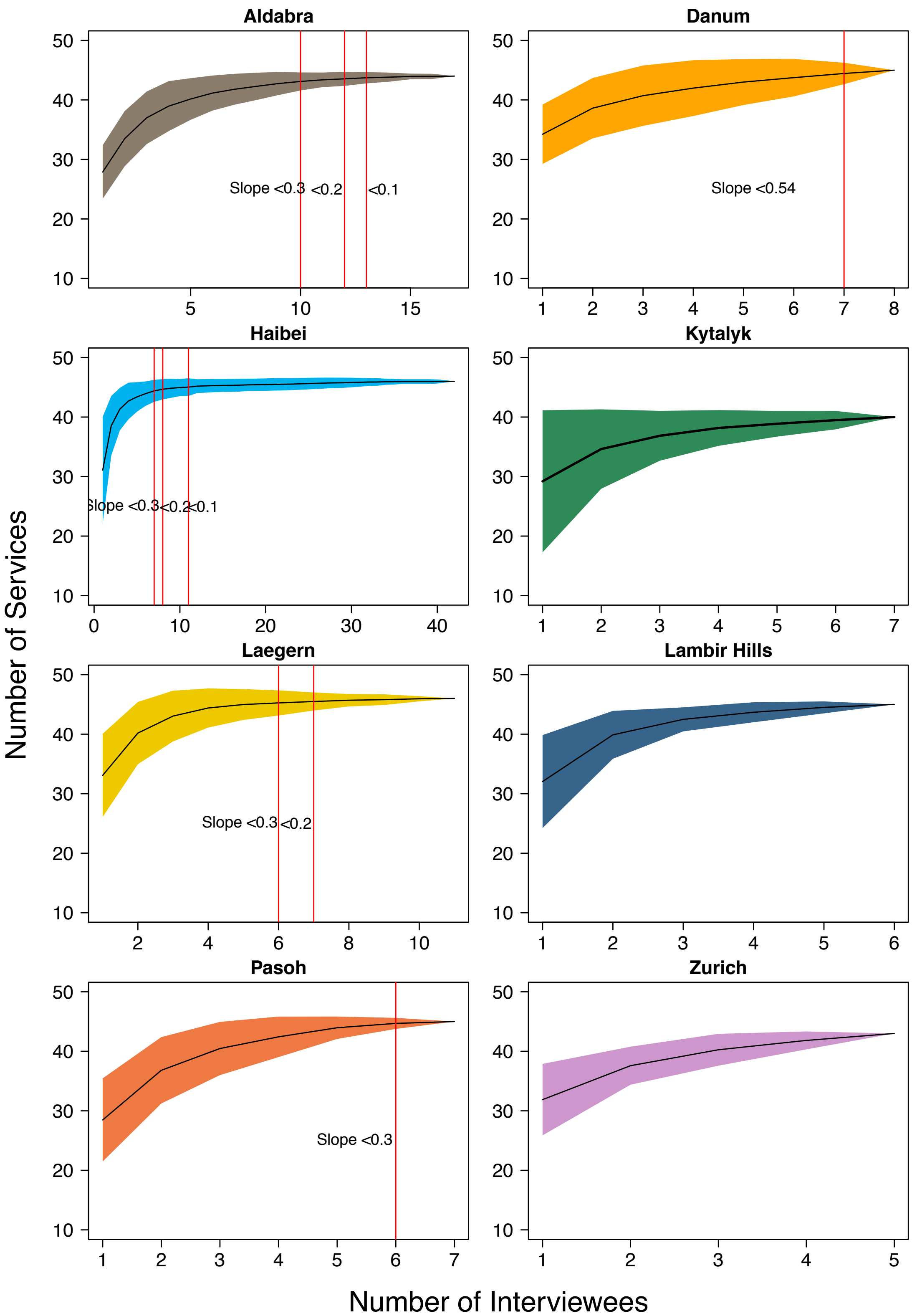

Figure 2: Accumulation curves for all research sites. Aldabra, Haibei, Laegern and Pasoh saturate (majority of potential services captured). Vertical lines indicate approximate number of interviewees for slopes less than 0.3, 0.2 and 0.1. Danum, Kytalyk, Lambir Hills and Lake Zurich do not saturate. With a higher number of interviewees, Danum is included in further analyses.

3.2 Presence and Importance of Ecosystem Services

3.2.1 Services that are present at all research sites

I used the mean presence scores greater than 0.65 to indicate presence of an ecosystem service. These scores are used to indicate how many services are perceived to be present at the research sites (figure 3). With regard to the total number of services present, Lambir has the highest number (34) and Aldabra and Pasoh each have the least (22).

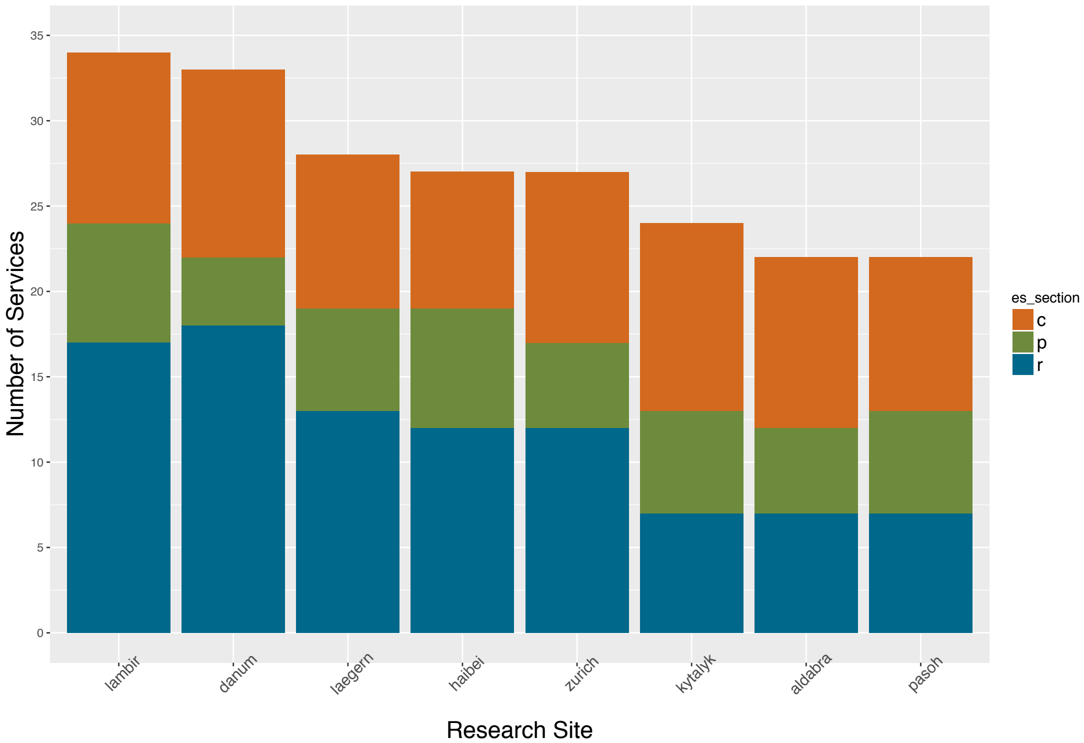

Figure 3: Number of services (mean presence score >0.65) perceived as present at each research site. c (orange) = cultural services; p (green) = provisioning services; r (blue) = regulating services.

Across the three sections (cultural, provisioning and regulating services), there is little variation in the number of cultural services perceived to be present at the sites. This might be expected since there are fewer services in this section (9-11 of 11 possible services). While there is some variation in the numbers of provisioning services perceived to be present (4-7 of 16 services), the most variation is in perceptions of the 21 regulating services. There are 18 services that are perceived to be present at Danum but only seven at Aldabra, Pasoh and Kytalyk. Differences in the numbers of regulating services would seem to be driving the overall numbers of services perceived to be present at the sites. This may be related to the system being described, as the three sites with the highest numbers of regulating services are forests, although Pasoh Forest Reserve is amongst the sites with the fewest.

I also looked at the number of sites where each service is perceived to be present (figure 4). Across the full dataset, there are only ten ecosystem services that have presence scores equal to or greater than 0.65 at all sites, showing high certainty that the service is present (figures 4 & 5). Eight of these are cultural services, and two are regulating (39 and 48). Services 3 (scientific) and 7 (aesthetic) score higher than 0.9, six are above 0.75 (1 (experiential use), 2 (physical use), 4 (educational), 10 (existence), 11 (bequest) and 39 (pollination and seed dispersal)). Ecosystem services 6 (entertainment) and 48 (micro and regional climate regulation) are above 0.65. Services 5 (entertainment) and 40 (decomposition and fixing processes) have high certainty at seven research sites. There are 31 services perceived to be present at at least half of the research sites.

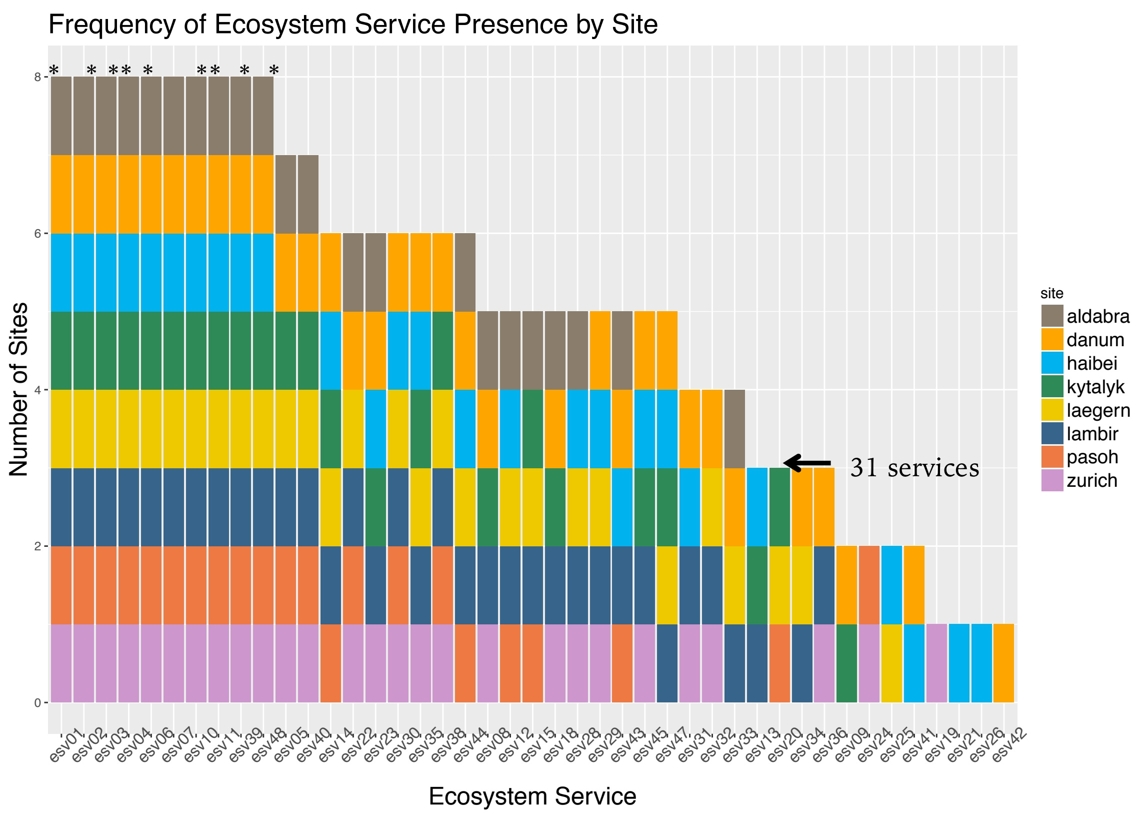

Figure 4: Ecosystem services perceived to be present at research sites (mean presence greater than 0.65). * indicates mean score greater than 0.75, ** greater than 0.9. 43 services shown.

No services are definitively absent from all sites, but five do not score 0.65 or above at any sites (16 & 17 animal and plant based aquaculture, 27 animal based energy, 37 storm protection, and 46 chemical condition of salt waters). Overall there seems to be relatively high certainty about the presence of cultural services (figure 5).

There are also services that score 0.35-0.65, indicating that interviewees gave mixed responses about whether a service is present or absent. This data is discussed in further detail in section 3.3 below.

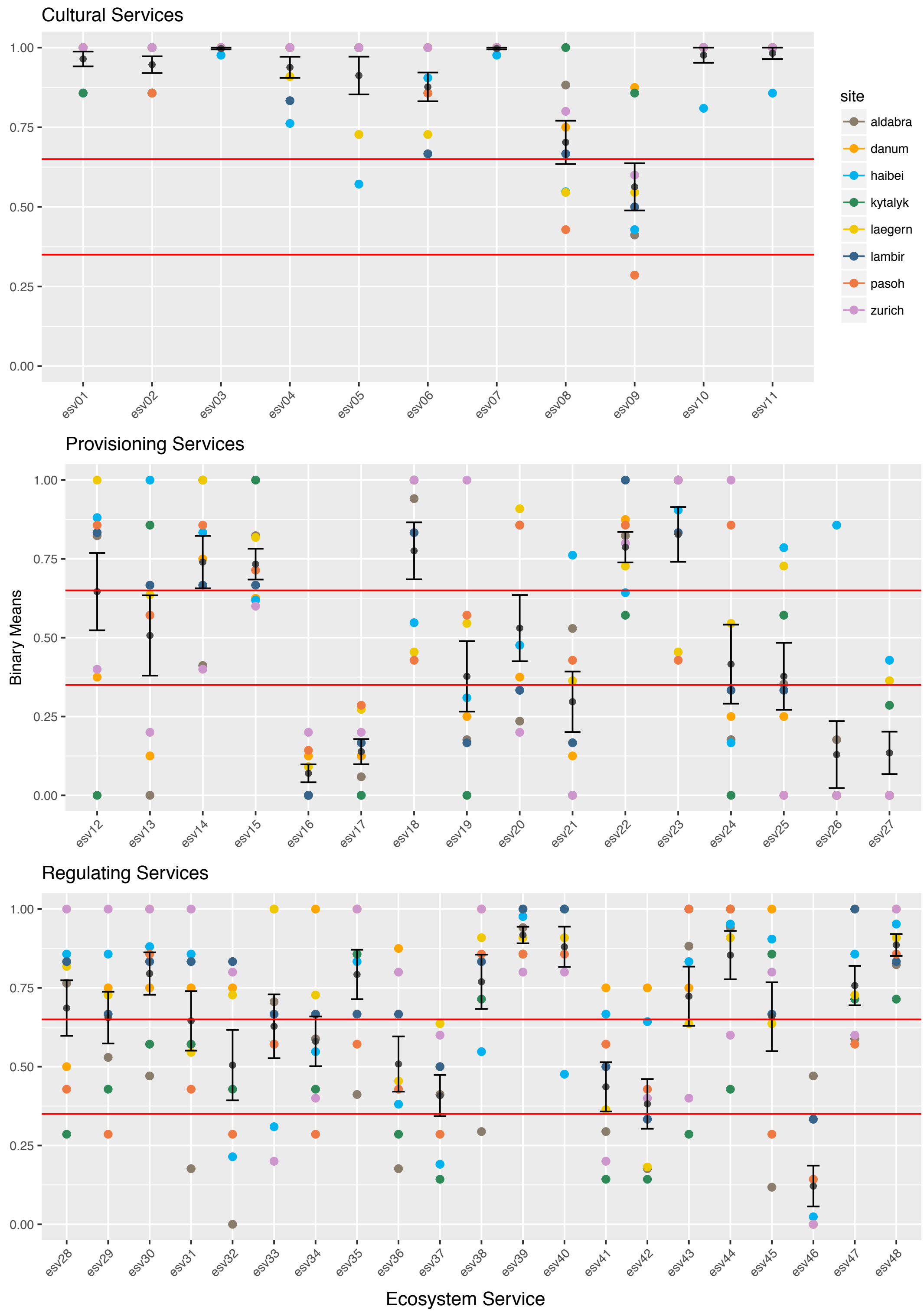

Figure 5: Mean presence scores for each ecosystem service. Boxes show cultural, provisioning and regulating sections. Coloured points are site means, black points show overall data mean and se. Points above and below horizontal red lines (y = 0.35, y = 0.65) signal certainty about the presence/absence of the ecosystem service. Points between lines indicate uncertainty about presence/absence of the service.

3.2.2 *Services that are important at all research sites*

Using the mean importance scores for each ecosystem service across the full data set, there are only six services that are of medium to high importance at all sites – 2, 3, 4, 7, 10 and 11. Four of these have high importance (3, 7, 10 and 11) and two also have very high certainty (3 and 7). All six services are cultural services. The strengths of the importance of the different services at each site can be seen in the heat map (figure 6) and the mean scores plot (figure 7).

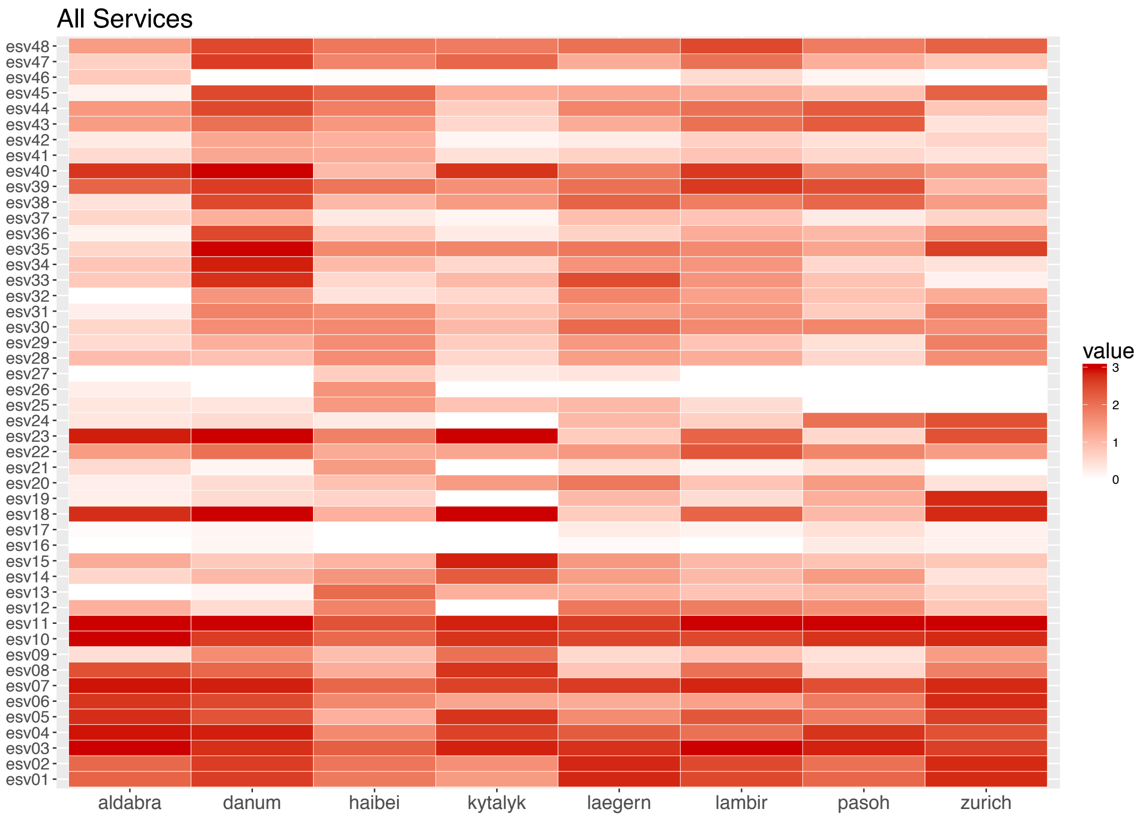

Figure 6: Heatmap showing relative importance of ecosystem services at research sites. Darker red are high importance, white cells indicate absence of service. ESV01-ESV11 are cultural services; ESV12-ESV27 are provisioning services; and ESV28-ESV48 are regulating services.

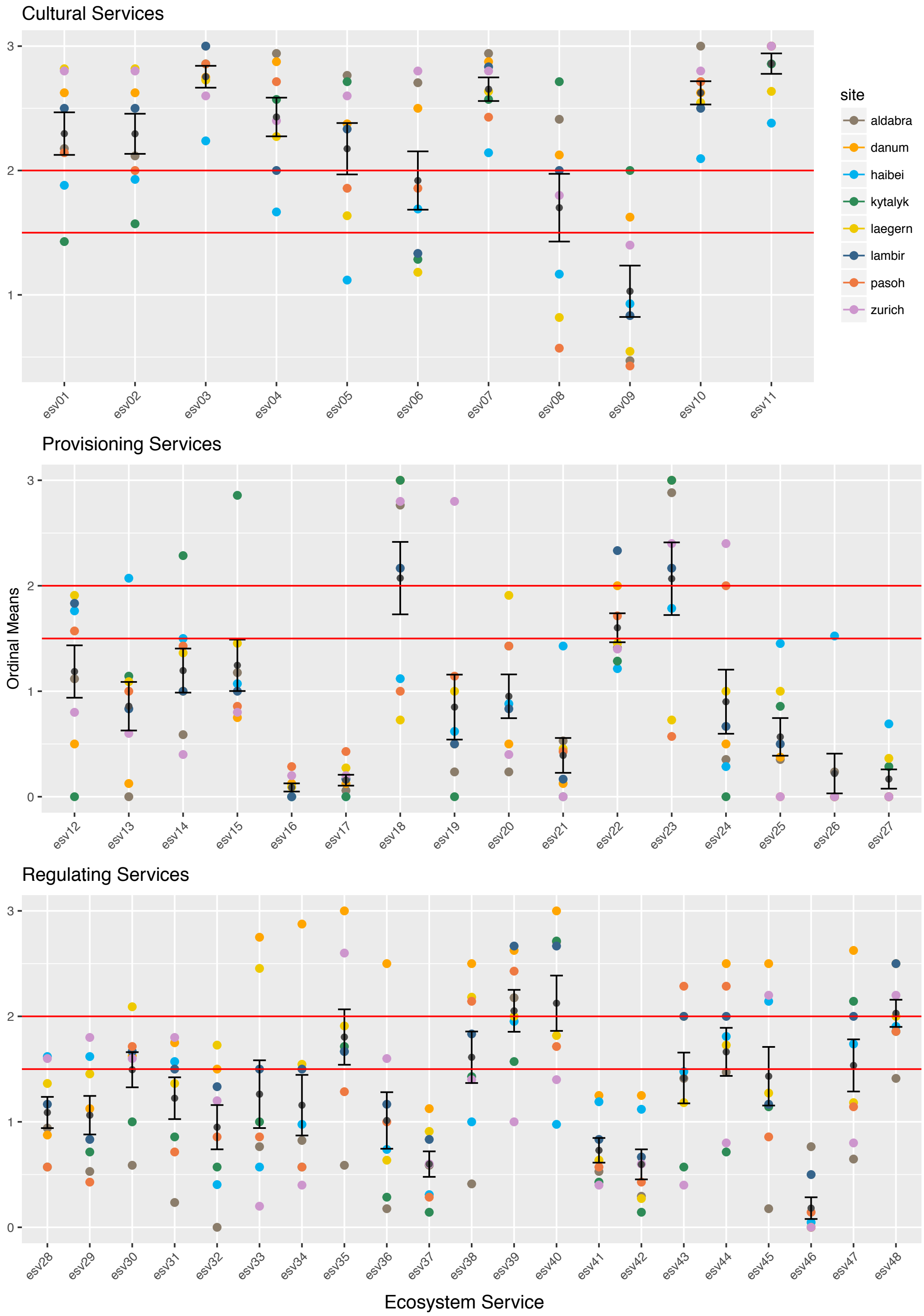

Figure 7: Mean importance scores for each ecosystem service at sites. Coloured points are site means, black points show overall data mean and se. Horizontal red lines indicate medium importance (y intercept 1.5), and high importance (y intercept 2).

3.2.3 *Services unique to research sites*

I consider services that have mean presence scores above 0.65 at one site and below 0.35 (negative certainty) at all others to be unique to that site. Of all 48 ecosystem services, animal-based resources (26) is the only service to show positive certainty at one site, (Haibei), with all other scores below 0.35. A further three have positive certainty scores at one site, with mixed negative and uncertainty scores at others. These are ground water for drinking (19) at Lake Zurich, materials from plants, algae and animals for agricultural use (21) at Haibei, and disease control (42) at Danum Valley. There are three more services that score 0.65 or above at only two sites: ground water for non-drinking purposes (24) at Pasoh and Lake Zürich, plant-based resources (25) at Haibei and Laegern, and pest control (41) at Danum and Haibei. These scores can be seen in the data ranges in figure 4 above. In general these more specific services are provisioning (with the exception of 41 and 42), suggesting that some sites provide material resources not available, or at least not used, at others. For example, the availability and use of ground water at Lake Zurich.

3.2.4 *Service composition at each site*

Using the same criteria as for the analyses across the full data set to construct baseline indications of the suite of ecosystem services at the research sites, I can show services that are both present and highly important at each site. The sections below describe those services with high certainty and/or importance at each site. Maximum certainty is a mean presence score of 1 and maximum importance is a mean importance score of 3; high certainty and importance are presence scores greater than 0.65 and importance greater than 2. Medium to low importance is considered to be less than 2.

Aldabra presence and importance

There are three services with maximum certainty and importance at Aldabra (3, 10 and 11), and a further 11 with high certainty and importance (1, 2, 4, 5, 6, 7, 8, 18, 23, 39 and 40). Seven services have high certainty but low importance (12, 15, 22, 28, 33, 43, 44 and 48) (figure 8). This pattern of presence and importance in part reflects Aldabra’s protected status (food provisioning is only possible on a very restricted scale) and small size – regulating services are present but many only occur at small scales. The provision of surface water for both drinking and non-drinking purposes is important on Aldabra atoll and the site is also perceived as very important for regulating nursery populations, and pollination and seed dispersal.

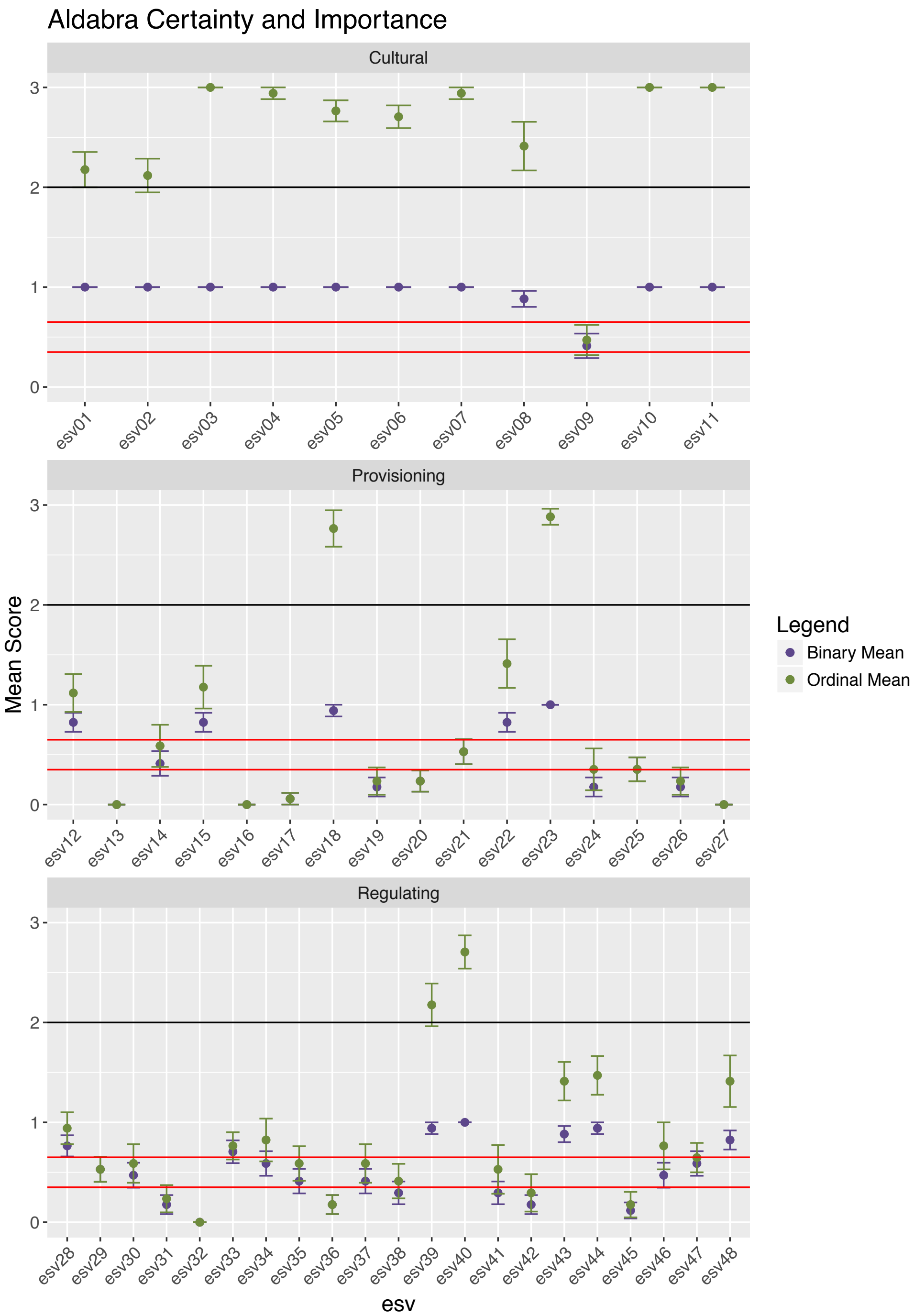

Figure 8: Presence (binary mean) and importance (ordinal mean) scores for ecosystem services on Aldabra Atoll.

Danum presence and importance

At Danum Valley, five services have maximum certainty and importance (11, 18, 23, 35 and 40). Twenty more have high scores for both and seven services have high certainty but low importance (9, 14, 29, 30, 31, 32, 41 and 42) (figure 9). The higher number of regulating services perceived to be present and important reflects that this is a large, tropical forest providing habitat, contributing to air and water regulation, and also providing water resources.

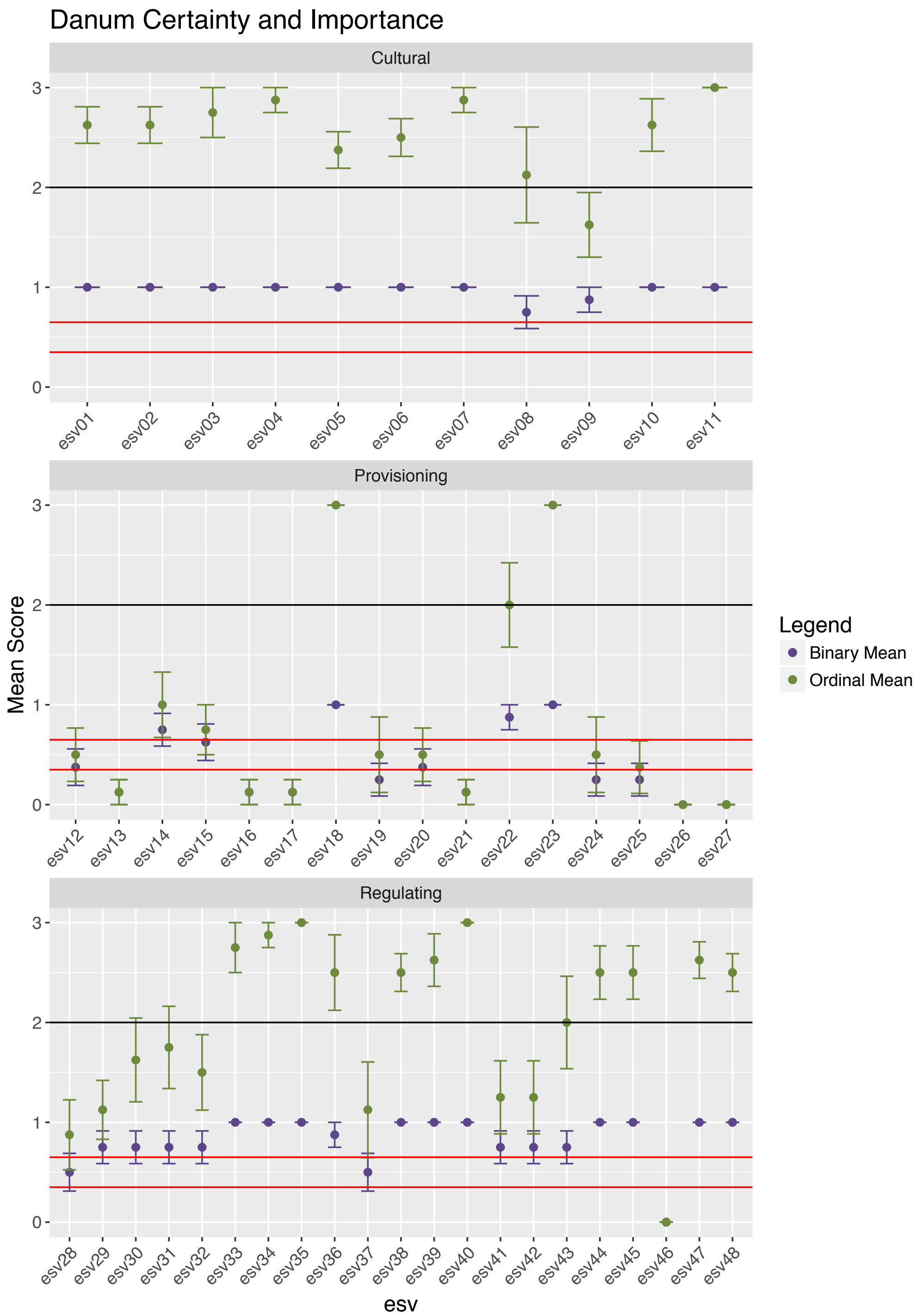

Figure 9: Presence and importance scores for ecosystem services at Danum Valley.

Haibei presence and importance

There are no services at the Haibei site with maximum certainty and importance scores, and only six have high certainty and importance (3, 7, 10, 11, 13 and 45). 21 have high certainty but low importance (figure 10). The lack of high scores may be due to the large number of interviewees for this site (42) but may also reflect a lack of familiarity either with the site or the ecosystem services concept. However, there is evidence here that interviewees see Haibei as important for providing resources for reared animals, and maintaining the chemical condition of freshwaters.

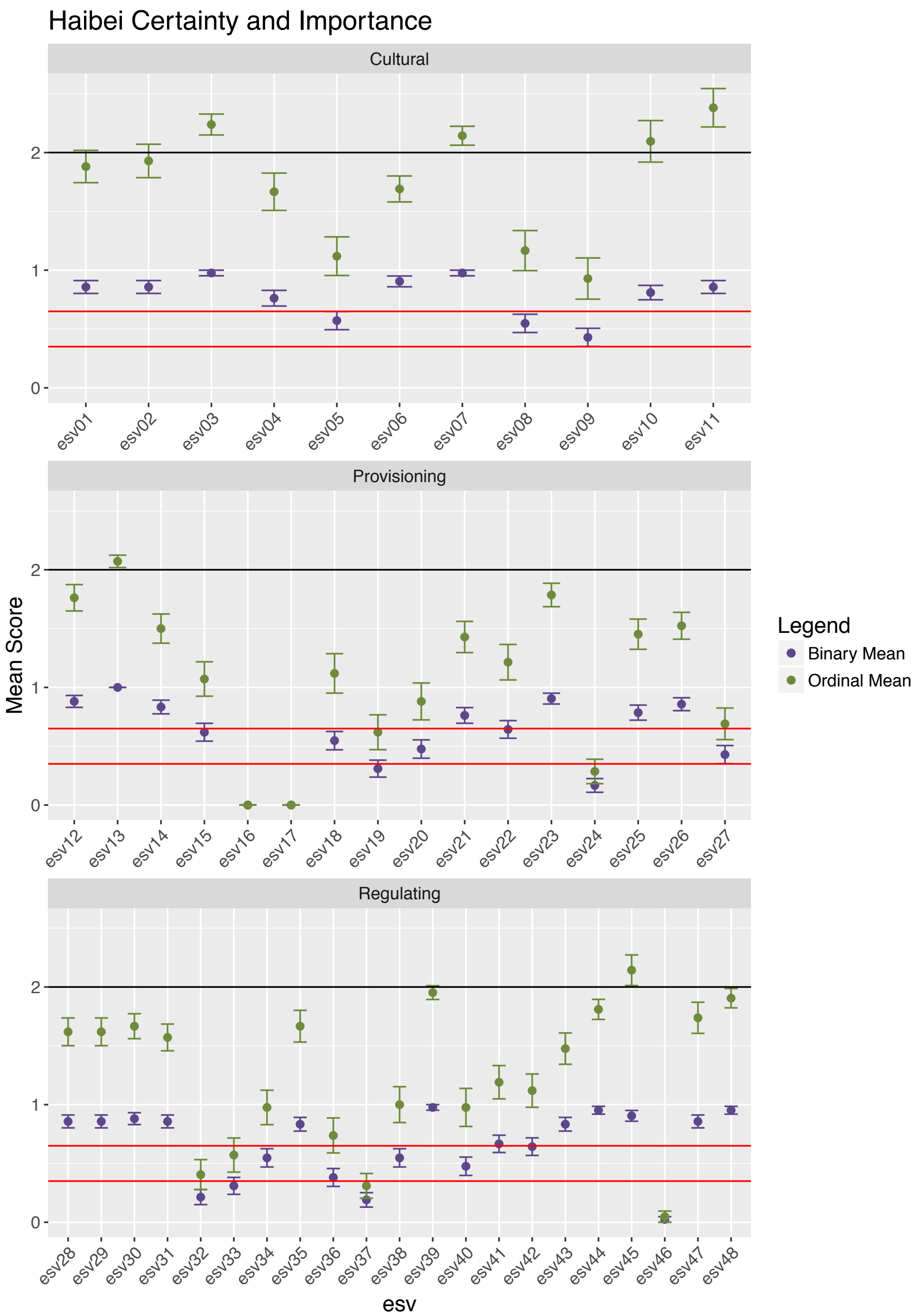

Figure 10: Presence and importance scores for ecosystem services in Haibei.

Kytalyk presence and importance

Services 18 and 23 (drinking water) have maximum certainty and importance scores at Kytalyk. Eleven have high scores for both, and eight have high certainty but low importance (6, 13, 20, 35, 38, 39, 45 and 48). Service 47 has high importance but low certainty (figure 11). Except for services 14 and 15 (wild plants and animals), the lack of provisioning services shows the low availability of resources at this high arctic site. As Kytalyk is embedded in a vast ecosystem, people perceive that it contributes to a number of system wide regulating services, such as global climate regulation.

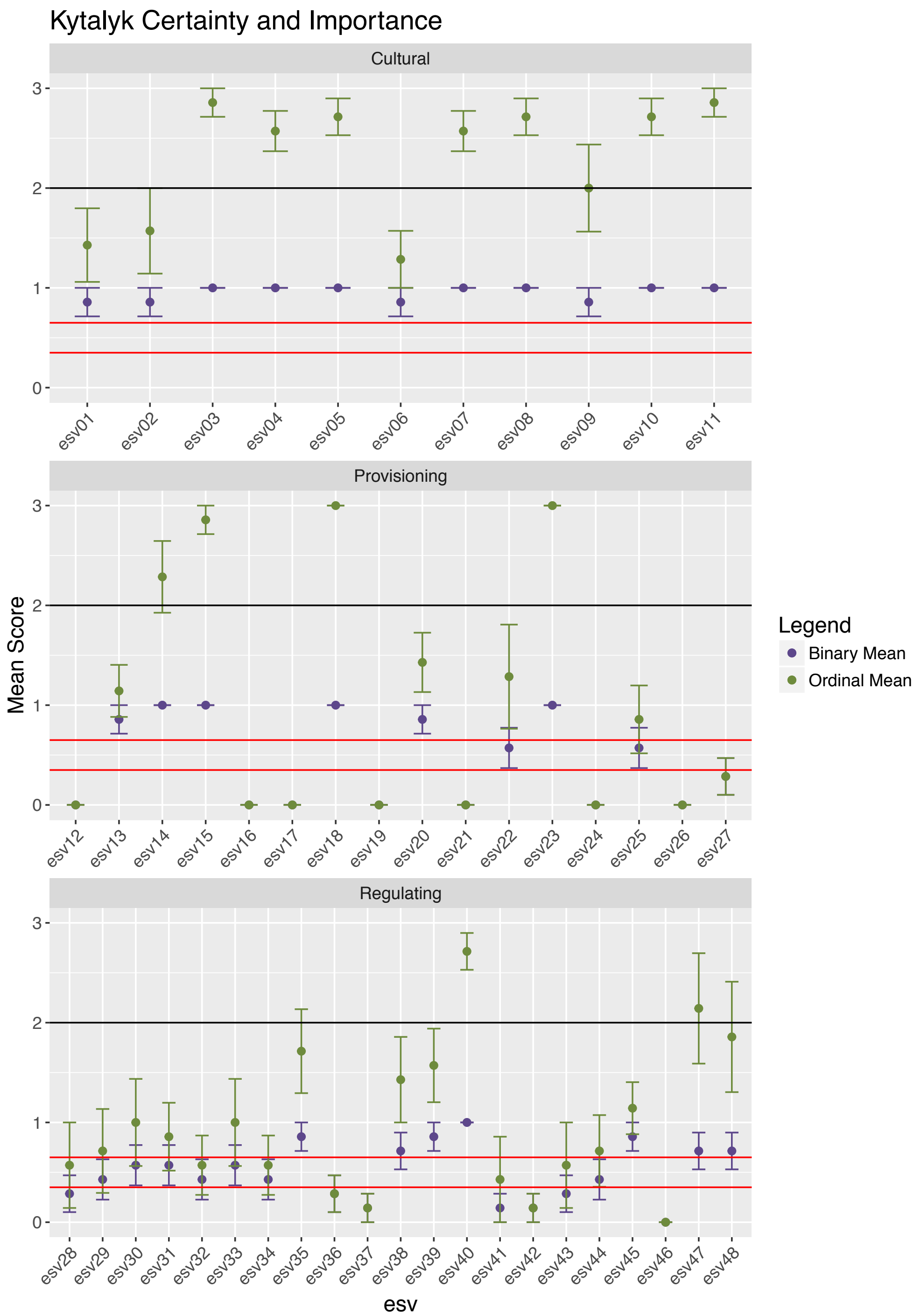

Figure 11: Presence and importance scores for ecosystem services at Kytalyk.

Laegern presence and importance

The Laegern site has no services with maximum certainty and importance scores. Twelve services have high certainty and importance (1, 2, 3, 4, 7, 10, 11, 30, 33, 38, 39 and 48); sixteen have high certainty but low importance (figure 12). All are either cultural or regulating services. As a protected forest that is popular for hiking, this is an expected result, as is the importance of services that filter airborne pollutants, control erosion and regulate the local microclimate.

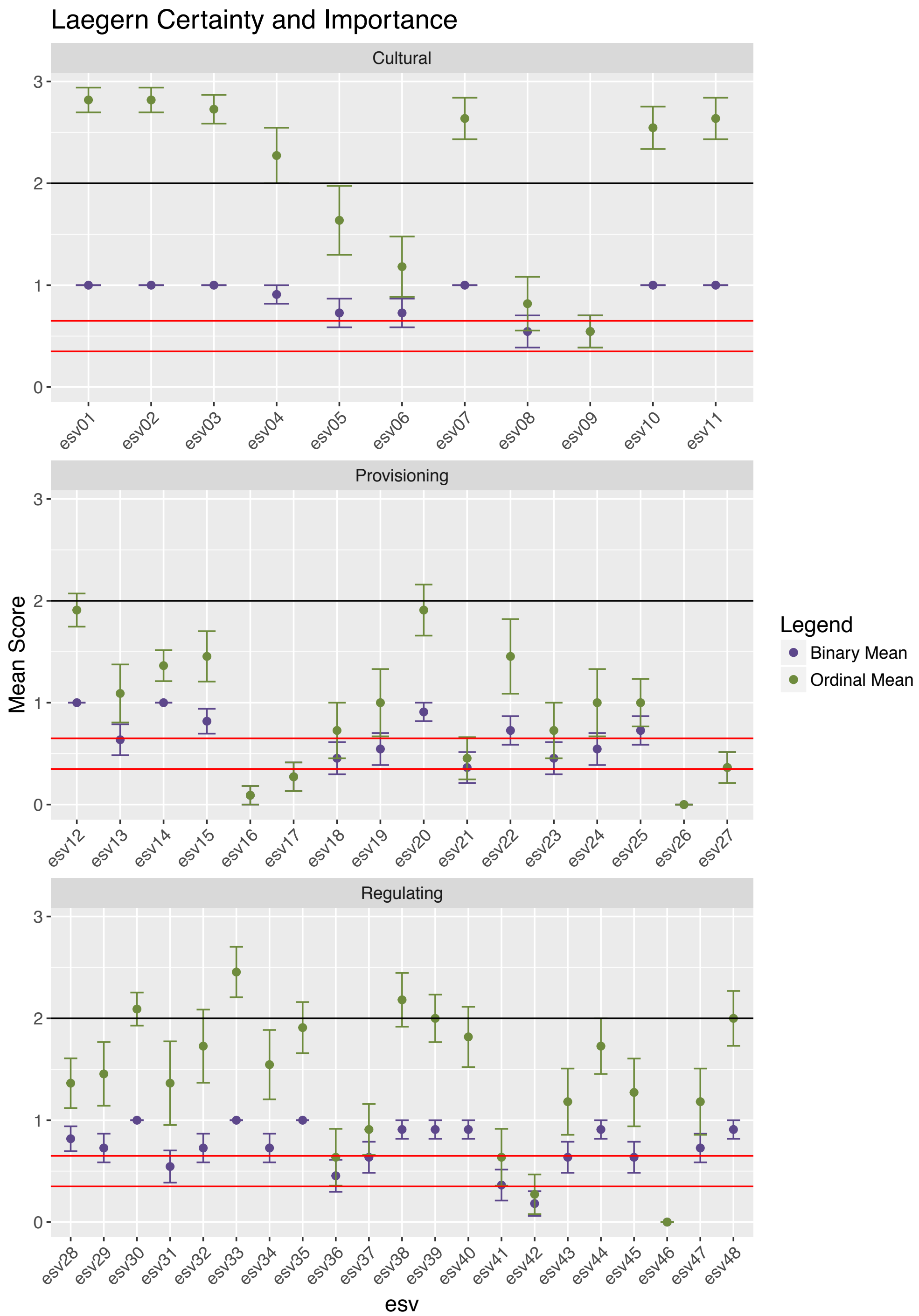

Figure 12: Presence and importance scores for ecosystem services at Laegern.

Lambir presence and importance

Two services are perceived with maximum certainty and importance at the Lambir site (3 and 11). Sixteen services have high certainty and importance, and 15 have high certainty but low importance (figure 13). Important services here are on the whole cultural and regulating, indicating that the site is used recreationally and that it is perceived to be important in providing drinking water, maintaining soil properties, regulating pollination and nursery populations, and regional and global climate.

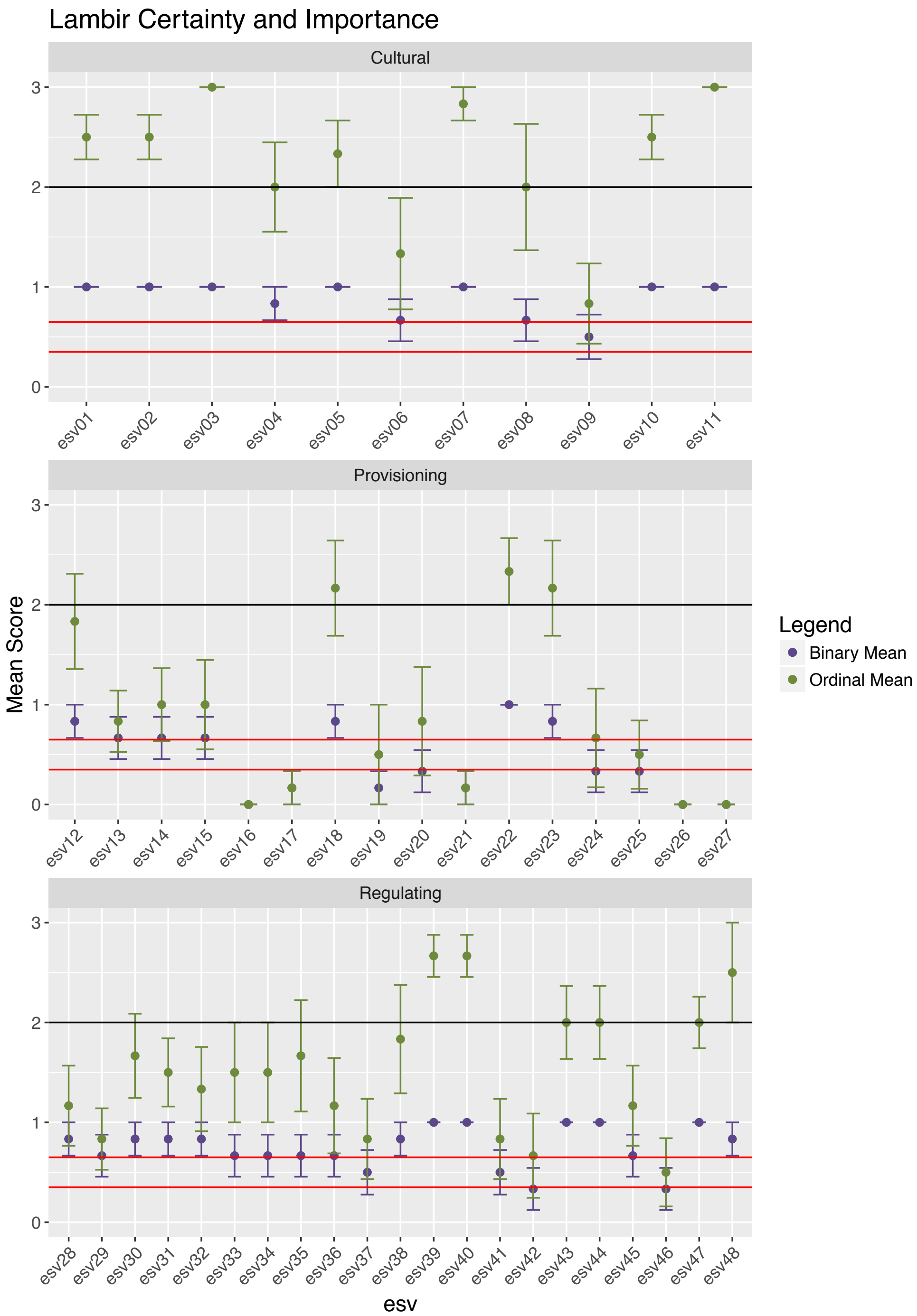

Figure 13: Presence and importance scores for ecosystem services at Lambir Hills.

Pasoh presence and importance

One service at Pasoh has maximum certainty and importance (11); eleven have high certainty and importance (1, 2, 3, 4, 7, 10, 24, 38, 39, 43 and 44), and ten services have high certainty and low importance (5, 6, 12, 14, 15, 20, 22, 30, 40 and 48) (figure 14). The clearest scores are for cultural services with limited representation of provisioning services. It is a research area within a wider forest landscape, so higher scores for some regulating services such as ventilation, pollination and seed dispersal, soil formation, are expected.

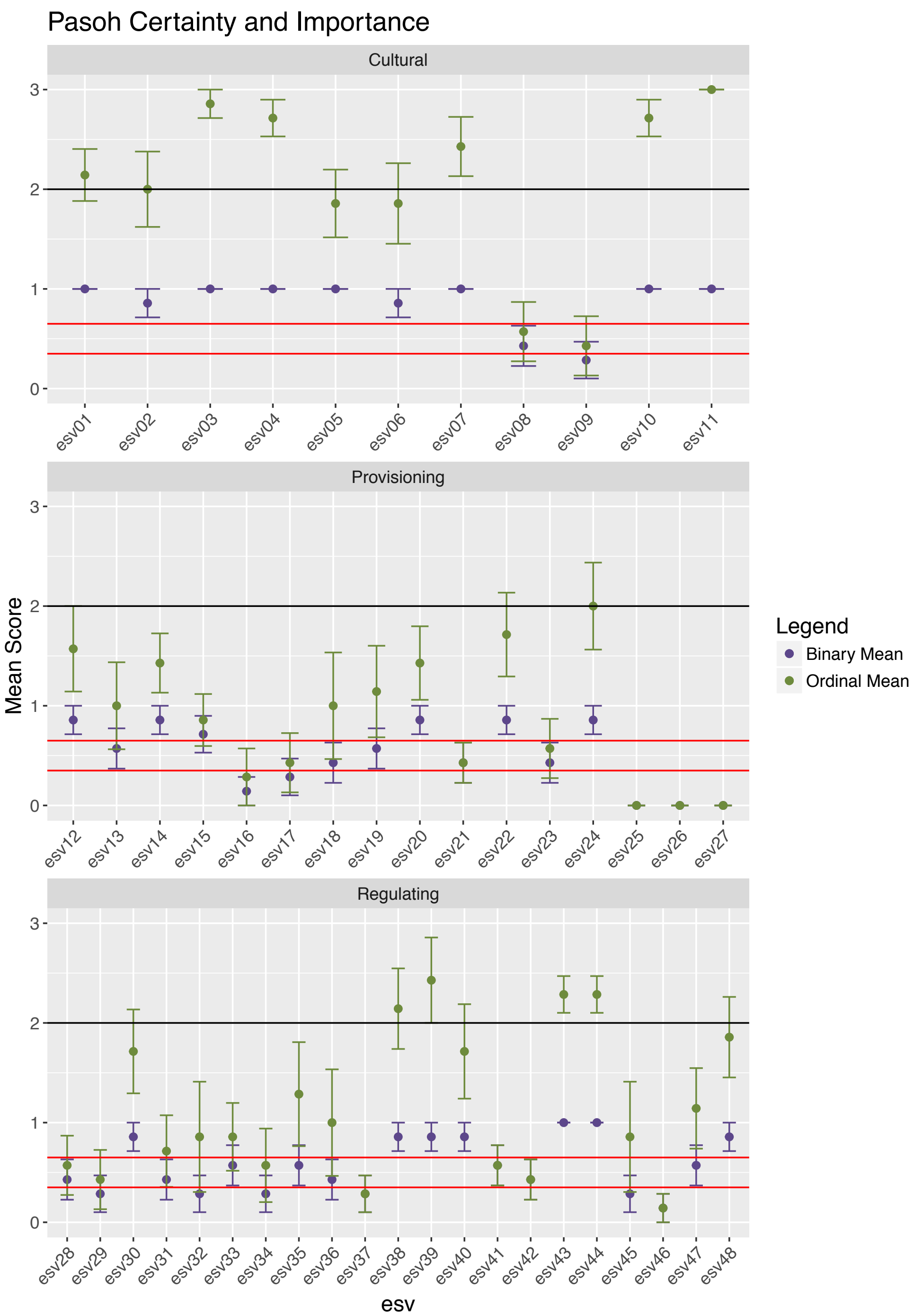

Figure 14: Presence and importance scores for ecosystem services at Pasoh.

Zurich presence and importance

One service has maximum certainty and importance scores (11) while fifteen have high scores for both. Eleven services have high certainty and low importance (figure 15). The majority of the high scores are for cultural services, all four water provisioning services are included as well as maintenance of both the hydrological cycle and the condition of freshwaters, reflecting the importance of Lake Zurich in providing water to the population that surrounds it.

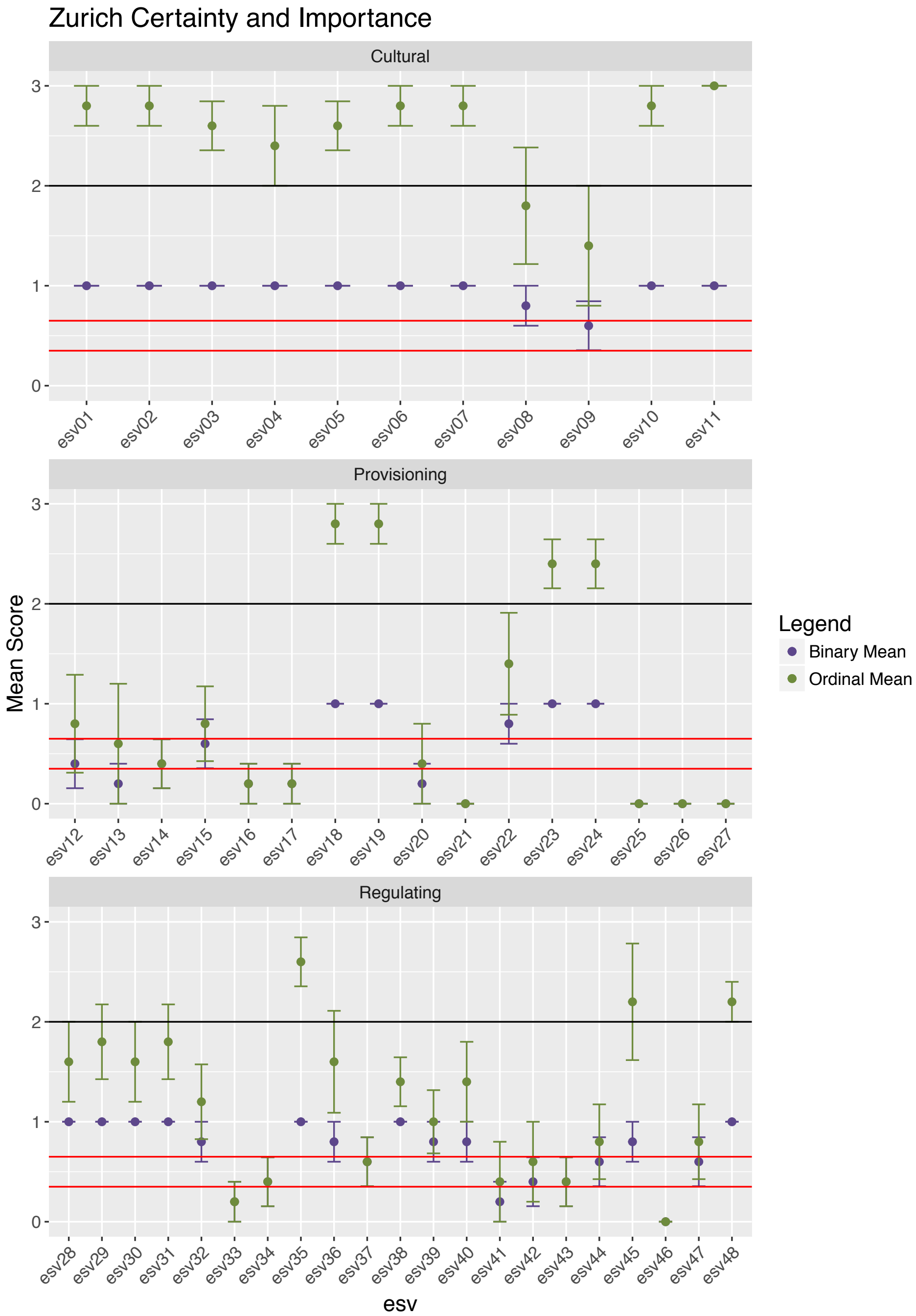

Figure 15: Presence and importance scores for Lake Zurich.

3.3 Uncertainty

3.3.1 Uncertainty across all sites

Some services are very clearly present or absent at individual sites and/or across all sites. However, there are also services that interviewees were unclear about, with mean scores between 0.35 and 0.65. This reflects that, at site level, some interviewees perceive that a service is present while others are not aware of it.

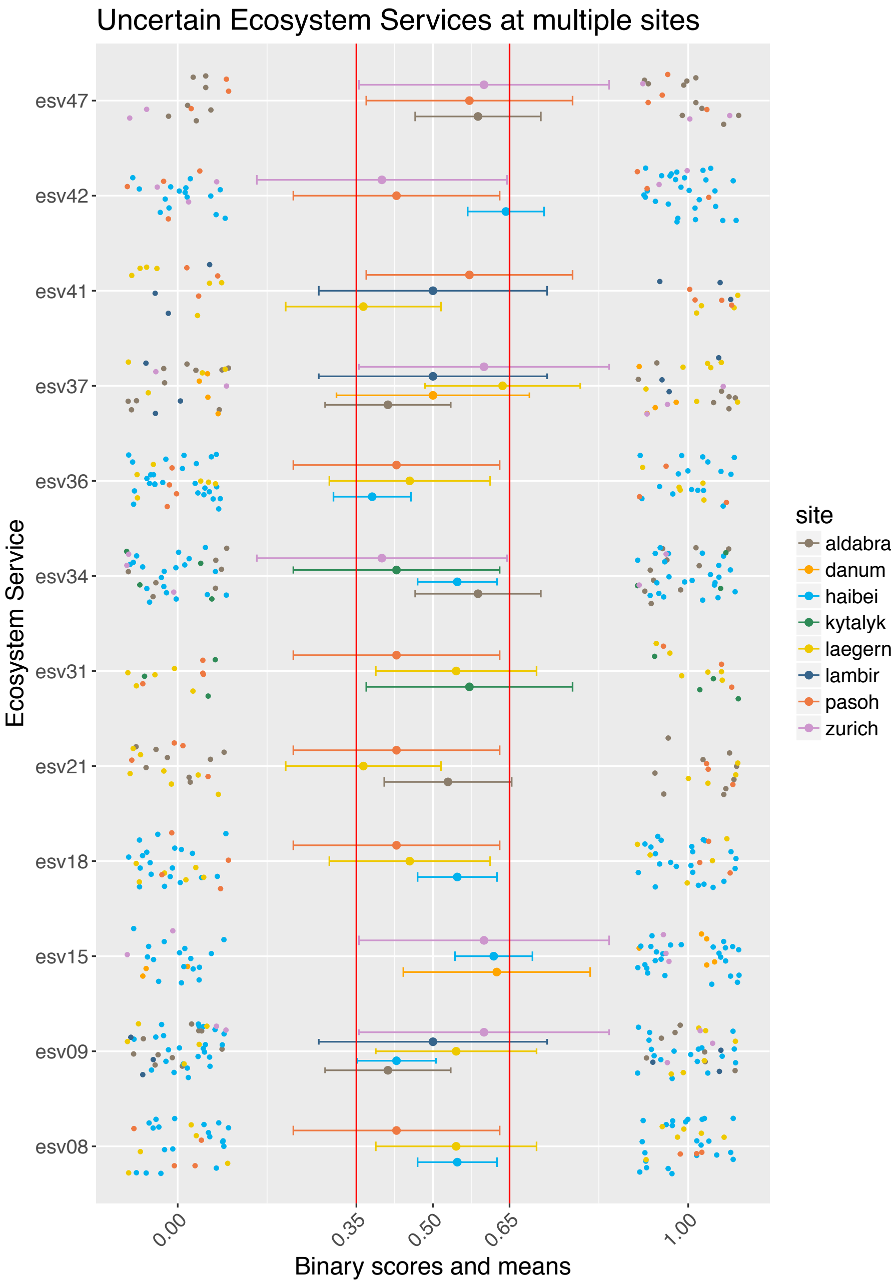

Figure 16: Sites and services with mean presence scores >0.35 and <0.65. Figure shows services that are uncertain at three or more sites.

Services at sites with uncertain perceived presence fall within the red lines on figure 16 (mean score between 0.35 and 0.65). No services that show uncertainty are present at all sites. Services 9 (sacred and/or religious) and 37 (storm protection) are uncertain at five sites, and 34 (buffering and attenuation of mass flows) is uncertain at four.

3.3.2 *Uncertainty at individual sites*

There are a number of services that were perceived with uncertainty by interviewees at the individual sites, and as figure 17 shows, there are differences in levels of uncertainty between the sites.

Eleven services have inconsistent responses from interviewees at Aldabra Atoll. One is a cultural service, three are provisioning, and the remaining seven are regulating.

At Danum Valley, interviewees were unclear about the presence of three provisioning and two regulating services. Interviewees for the Haibei research site gave mixed responses for thirteen services - three cultural, five provisioning and a further five regulating. There were variable responses for nine services at Kytalyk, two are provisioning and seven regulating. The most uncertainty in interviewees' perceptions of ecosystem services is at Laegern, where fifteen services had scores between 0.35 and 0.65. Two of these are cultural, seven provisioning and six regulating. Lambir Hills shows the least uncertainty about ecosystem service presence or absence with only three services that interviewees were unsure about. One is a cultural service and the other two are regulating. At Pasoh fourteen services were perceived uncertainly, one cultural, five provisioning and nine regulating. Finally, interviewees for Lake Zurich were uncertain about the presence of ten ecosystem services. One is a cultural service, three are provisioning and the rest are regulating services.

It appears that the most uncertain perceptions were about the presence of regulating services at each site. More regulating than either cultural or provisioning services elicited mixed responses from interviewees at five of the eight research sites.

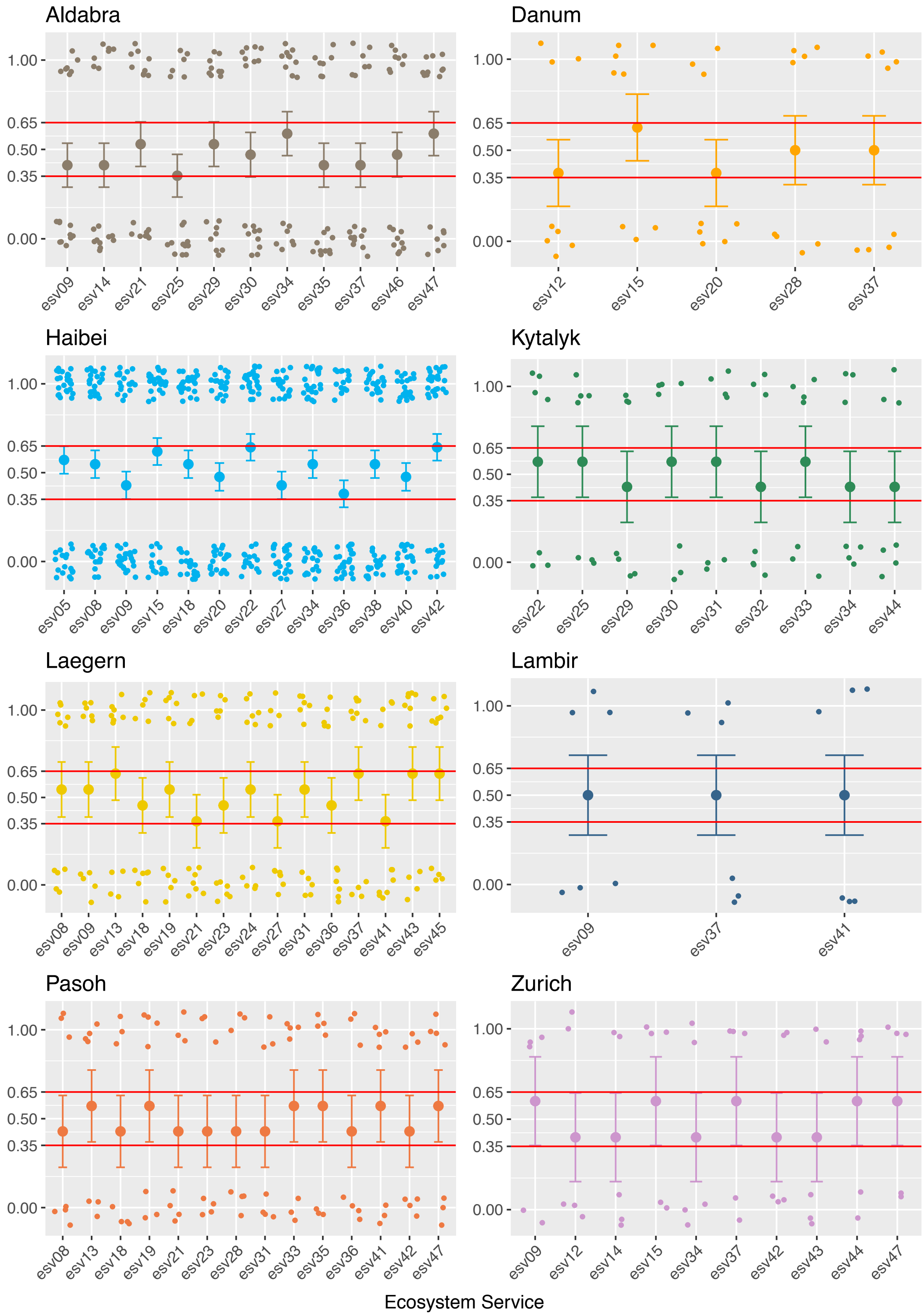

Figure 17: Uncertain services at individual sites, mean scores between 0.35 and 0.65.

3.4 Correlations Between Ecosystem Services

3.4.1 Correlations across sites

The correlation matrix below (figure 18) is calculated from the mean importance data from all sites. The data reflects the perceptions of interviewees about the presence and importance of ecosystem services at the research sites and the correlation matrix indicates where ecosystem services are positively and negatively correlated. As one increases another also increases or conversely, decreases. Consequently, I am suggesting that, for example, when someone perceives that a site mediates the impacts of noise or visual pollution (ESV32), it is also improving air quality through ventilation and transpiration (ESV38). It is also likely that in some cases interviewees perceive some services to be broadly the same, for example physical and experiential use (ESV01, ESV02 = 0.987), or pest and disease control (ESV41, ESV42 = 0.901) (See table 3).

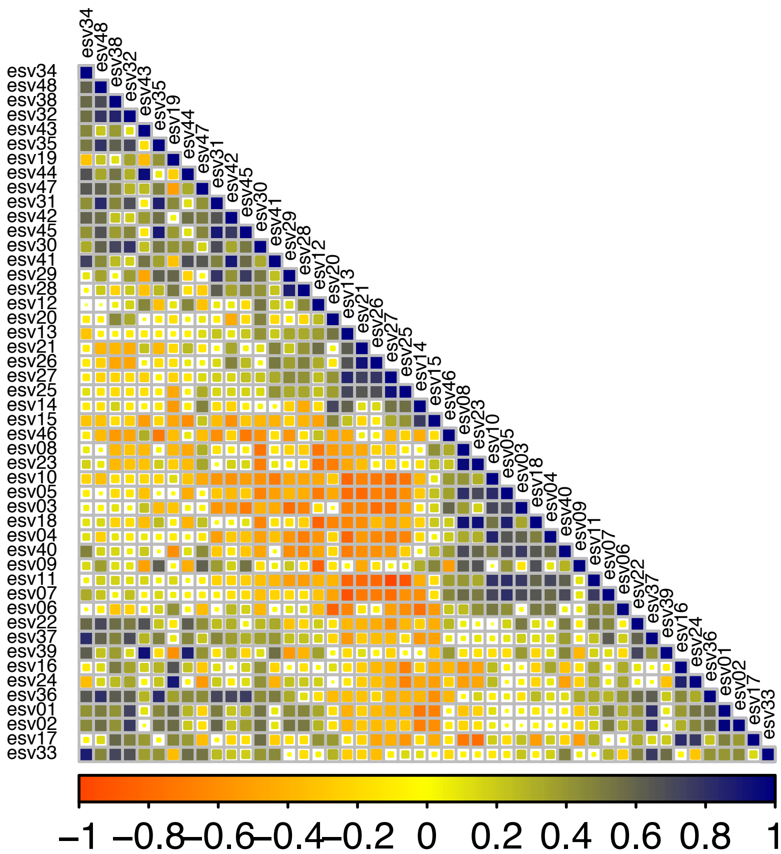

Figure 18: Correlation matrix of correlation coefficients between ecosystem services. Squares that are dark red indicate high negative correlations between services, dark blue squares indicate high positive correlations. Method = “Pearson”, order="AOE" (eigen vectors), total number of correlations = 1128.

esv_1	esv_2	correlation	class_1	class_2
esv01	esv02	**0.9866929**	Experiential use of plants, animals and land-/seascapes	Physical use of land-/seascapes
esv08	esv23	**0.9535674**	Symbolic	Surface water for non-drinking purposes
esv43	esv44	**0.9441323**	Weathering processes	Decomposition and fixing processes
esv18	esv23	**0.9394687**	Surface water for drinking	Surface water for non-drinking purposes
esv39	esv43	**0.9336634**	Pollination and seed dispersal	Weathering processes
esv25	esv27	**0.9331425**	Plant-based resources	Animal-based energy
esv21	esv26	**0.9246396**	Materials from plants, algae and animals for agricultural use	Animal-based resources
esv08	esv18	**0.9229501**	Symbolic	Surface water for drinking
esv31	esv45	**0.9074372**	Dilution by atmosphere, freshwater and marine ecosystems	Chemical condition of freshwaters
esv19	esv24	**0.9021253**	Ground water for drinking	Ground water for non-drinking purposes
esv41	esv42	**0.9010962**	Pest control	Disease control
esv35	esv45	**0.8954612**	Hydrological cycle and water flow maintenance	Chemical condition of freshwaters
esv33	esv34	**0.8874562**	Mass stabilisation and control of erosion rates	Buffering and attenuation of mass flows
esv39	esv44	**0.8838901**	Pollination and seed dispersal	Decomposition and fixing processes
esv28	esv29	**0.8814225**	Bio-remediation by micro-organisms, algae, plants, and	Filtration/sequestration/storage/accumulation by micro-organisms, algae, plants, animals
esv05	esv18	**0.8782607**	Heritage, cultural	Surface water for drinking
esv16	esv24	**0.8693379**	Plants and algae from in-situ aquaculture	Ground water for non-drinking purposes
esv31	esv35	**0.8631011**	Dilution by atmosphere, freshwater and marine ecosystems	Hydrological cycle and water flow maintenance
esv32	esv38	**0.856169**	Mediation of smell/noise/visual impacts	Ventilation and transpiration
esv04	esv10	**0.8537571**	Educational	Existence
esv13	esv27	**0.8534161**	Reared animals and their outputs	Animal-based energy

Table 3: Showing 21 positive correlations above 0.85 (85%). Brown cells are cultural services, green are provisioning, and blue are regulating.

Of the 1128 correlation scores for the data set, 48 are positive correlations greater than 0.75. As table 3 illustrates, the highest correlations are in general between services in the same ecosystem service sections (cultural, provisioning, regulating): 41 of the 48 (85.4%) positive correlations. Only three of the scores above 0.9 are correlations between services from different sections (symbolic and surface water for non-drinking purposes, symbolic and surface water for drinking, and heritage/cultural and surface water for drinking). It is notable that all three are correlations with use of water.

Table 4 also indicates that most negative relationships (below -0.75) are between cultural and provisioning services (84.2%). Only three of the 19 negative correlations do not follow this pattern. It seems that most negative relationships are between services that involve extraction of natural resources (energy, reared animals and crops, drinking water, and wild plants) and cultural use or relationships with the research site.

esv_1	esv_2	correlation	class_1	class_2
esv11	esv27	**-0.98201**	Bequest	Animal-based energy
esv07	esv13	**-0.92411**	Aesthetic	Reared animals and their outputs
esv11	esv25	**-0.90956**	Bequest	Plant-based resources
esv09	esv12	**-0.84622**	Sacred and/or religious	Cultivated crops
esv06	esv20	**-0.8311**	Entertainment	Fibres and other materials from plants, algae and animals for direct use or processing
esv11	esv13	**-0.82809**	Bequest	Reared animals and their outputs
esv12	esv18	**-0.82462**	Cultivated crops	Surface water for drinking
esv10	esv13	**-0.81858**	Existence	Reared animals and their outputs
esv04	esv13	**-0.81254**	Educational	Reared animals and their outputs
esv11	esv26	**-0.80269**	Bequest	Animal-based resources
esv11	esv21	**-0.8017**	Bequest	Materials from plants, algae and animals for agricultural use
esv05	esv21	**-0.79842**	Heritage, cultural	Materials from plants, algae and animals for agricultural use
esv07	esv27	**-0.78884**	Aesthetic	Animal-based energy
esv03	esv26	**-0.78395**	Scientific	Animal-based resources
esv03	esv29	**-0.77804**	Scientific	Filtration/sequestration/storage/accumulation by micro-organisms, algae, plants, animals
esv05	esv13	**-0.77496**	Heritage, cultural	Reared animals and their outputs
esv10	esv27	**-0.7706**	Existence	Animal-based energy
esv17	esv23	**-0.76225**	Animals from in-situ aquaculture	Surface water for non-drinking purposes
esv06	esv14	**-0.75747**	Entertainment	Wild plants, algae and their outputs

Table 4: Showing 19 negative correlations below -0.75 (-75%).

The general trend of positive, none and negative correlations is indicted in figure 19 showing the frequency of correlation scores and how they are distributed around 0 (positive and negative scores). The bars to the right of zero are in general bigger, indicating more positive than negative correlations.

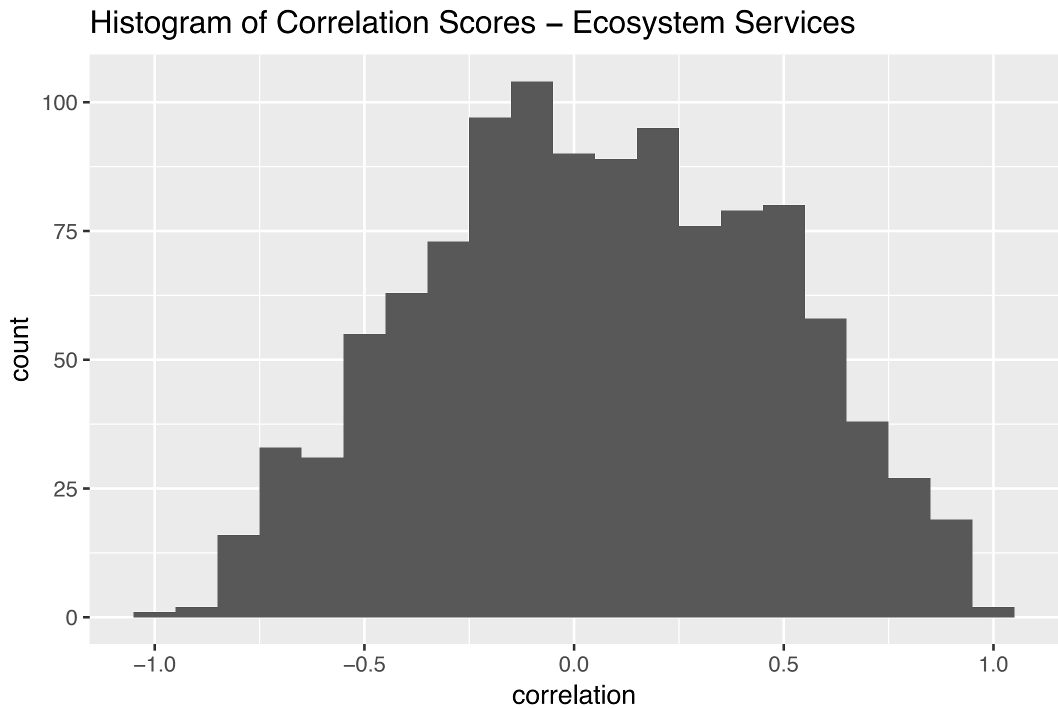

Figure 19: Frequency of positive correlations appears greater than negative.

Within the sections, cultural, regulating and provisioning services, the correlations appear to be quite different (figure 20). There are only nine cultural:cultural correlations (16.4% of all possible within-section correlations) below 0, none are below -0.5 with the lowest score in this section at -0.299 (indicating no correlation, between experiential use and symbolic value). Regulating:regulating services have nine coefficients below -0.5 (4.3% of all possible correlations) but none below -0.75. The lowest score within this section is -0.713 (chemical condition of salt waters and hydrological cycle). There are however, more negative correlations within the provisioning services. The lowest score is -0.825 (surface water for drinking, and crops), and a further 14 (12.5%) below -0.5.

Figure 20 illustrates this shift between sections, where correlations within and between cultural and regulating services appear to be more positive than negative. Provisioning services have a more mixed relationship, both to each other and the other sections, with a tendency towards negative correlations.

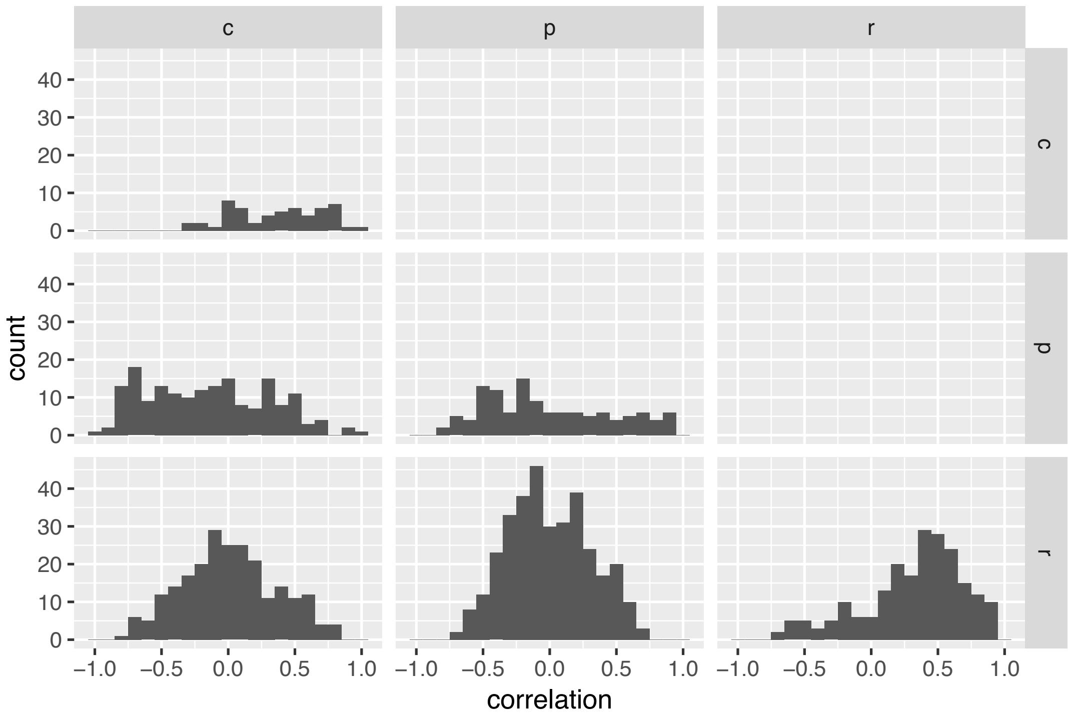

Figure 20: Histogram of correlations between ecosystem service sections – cultural, provisioning and regulating.

3.4.2 Correlations within sites

Due to limited data for some sites, it is possible to look at correlations for those with a reasonable number of interviewees (in brackets). Aldabra (17), Danum (8), Haibei (42) and Laegern (11) are discussed here. For the individual sites there are a number of missing services, either because they are not there at all (such as regulation of sea waters for inland sites), or because interviewees did not know (NA). It is possible that services that score 0, or are not present at the sites, appear in the correlation matrices. This is because it is still possible for the perception of absence of a service to be correlated with another service that is present.

The plots of the correlation coefficients for each site show clear differences between sites (figure 21), with stronger correlations at some (Danum and Laegern) and few or weaker correlations at others (Haibei). It is also again possible to discern how far services within sections correlate with each other and if there are patterns of negative or positive correlations between sections (figure 22).

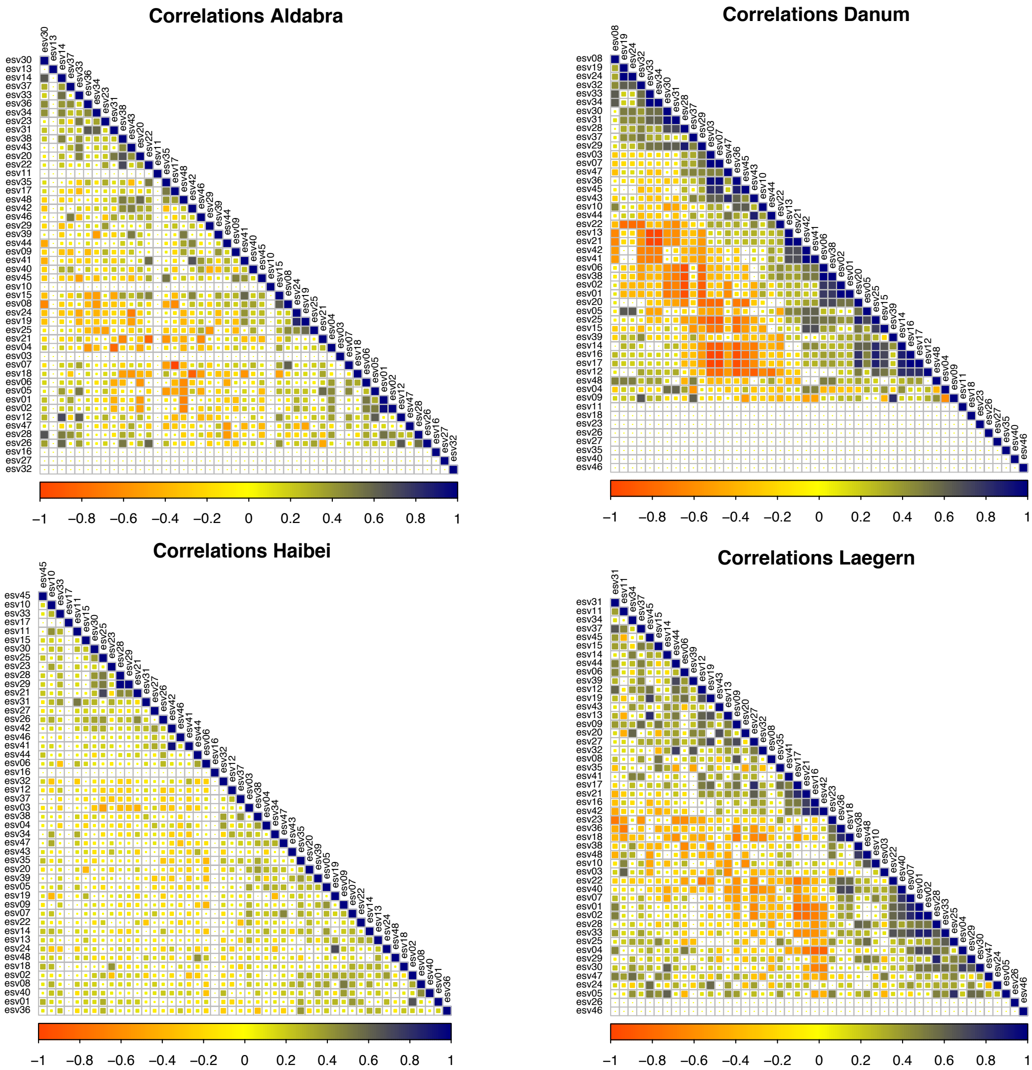

Figure 21: Correlation matrices for four research sites: Aldabra Atoll; Danum Valley; Haibei; Laegern. White cells indicate no correlation and complete lines show services that are not correlated with any others. This may include services that are not perceived to be present at the site. Ecosystem services are not in the same order for each site.

On Aldabra, while there are some highly correlated services, only two pairs have correlation coefficients above 0.75, both of which are conceptually similar services (1 and 2, and 19 and 24). Four show strong negative correlations (below -0.75), with three of these negative relationships with provisioning services. Of the seven services with no correlations, four (13, 16, 27, 32) are not present at the site. Danum has the highest number of strong correlations, with 33 above 0.75 and 41 below -0.75. There are a large number of scores of 1/ -1, and three of the eight services with no correlation are not present at the site (26, 27, 46). All but two positive correlations are between services in the same sections and all negative correlations except four are between services from different sections. The site with the fewest strong correlations is Haibei, with only two above 0.75 (bio-remediation by micro-organisms and filtration by micro-organisms, and pest and disease control) and none below -0.4. The strongest positive correlations are between regulating services, while negative correlations are between cultural and provisioning services. There are only two services that do not correlate with any others (16 and 17) and these are both absent from the site. Laegern also has a high number of strong positive correlations, with 17 over 0.75. More than half of these are between services from different sections, a different pattern to the other sites. There are seven correlations below -0.75, mostly between cultural and provisioning services and only two non-correlating services, both of which are absent (26 and 45).

At all sites except Laegern, higher positive correlations are between services from the same sections, 67.7% of scores over 0.75. All four sites have high positive correlations between ecosystem services 1 and 2 (experiential and physical use, 0.674-1). Negative correlations are very varied. Haibei has none below -0.48, while there are eight correlations equalling -1 at Danum. The pattern of scores between and within sections is stronger, with 45 of 52 (86.5%) below -0.75 between services from different sections. There are no shared negative correlations at the lower end of the scores.

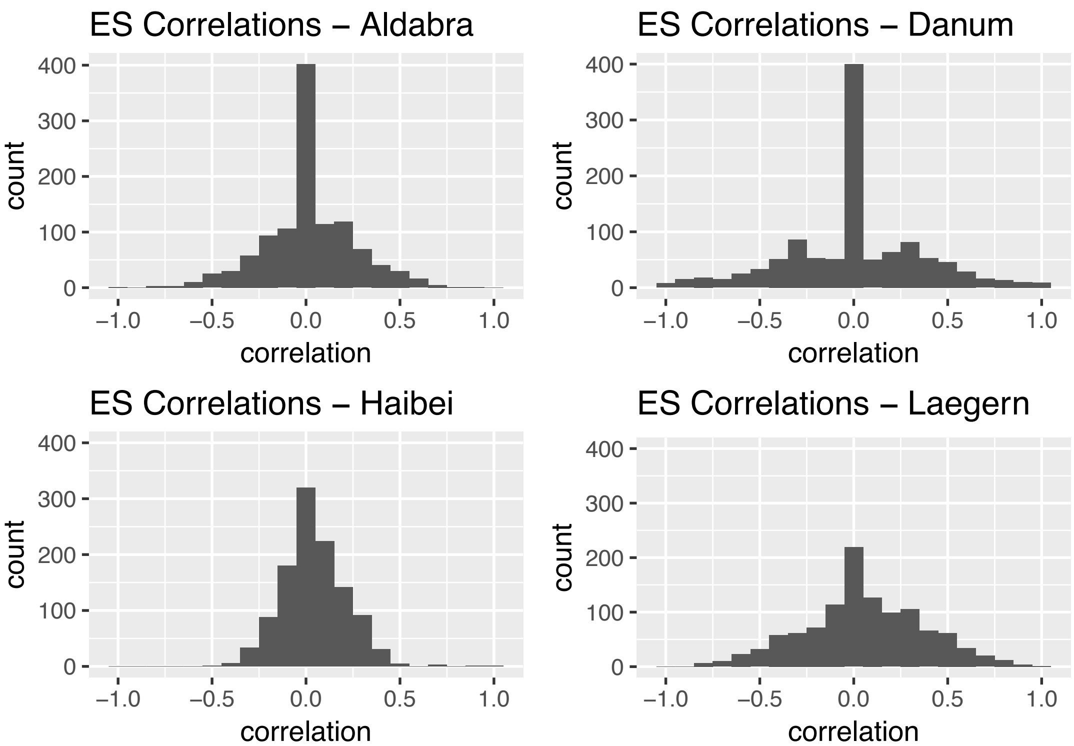

Figure 22: Histograms of correlation coefficients for four research sites. Tails to the left indicate more negative correlations, tails to the right are positive. Bars around zero indicate no correlation.

This variability in coefficients can be observed when comparing the left tails of the histograms (figure 22). A wider spread of the data suggests a wider range of scores but also higher positive and negative scores. The data for Danum is widely spread, while that for Haibei has a much narrower range.

3.5 Similarity and Difference

The patterns of correlations described above give an indication of how different the perceptions of the sites are. That is, the services that correlate – either positively or negatively – differ between sites.

3.5.1 Similarity and difference between sites

I used scatterplots to visually inspect how similar or different the ecosystem service correlation coefficients are between sites. Figure 23 shows the pairwise comparison of correlation scores from each site. The nearer points are to the line, the more similar the scores (correlations) are. The large number of data points makes any visual interpretation difficult but in general, the points are spread very widely around the line, and in quite different patterns, suggesting large dissimilarities between the sites.

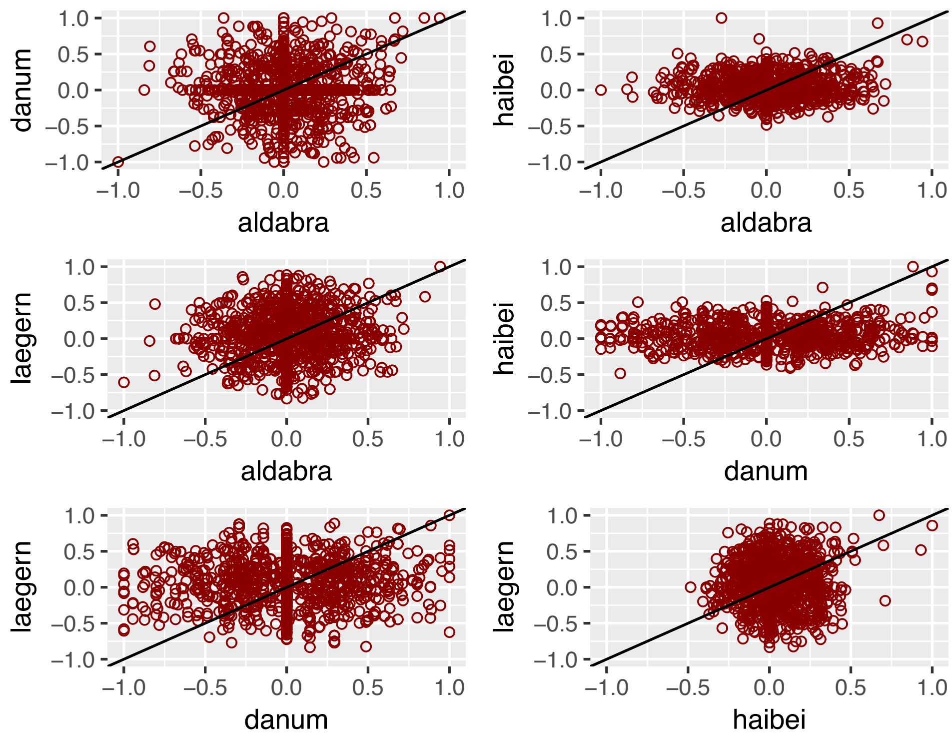

Figure 23: Scatter plots of all correlation scores between sites.

I also assessed the section scores (figures 24-26), to reduce the number of data points. Cultural scores for Aldabra and Haibei cluster nearer to the line, suggesting more similarity but overall the patterns are very different.

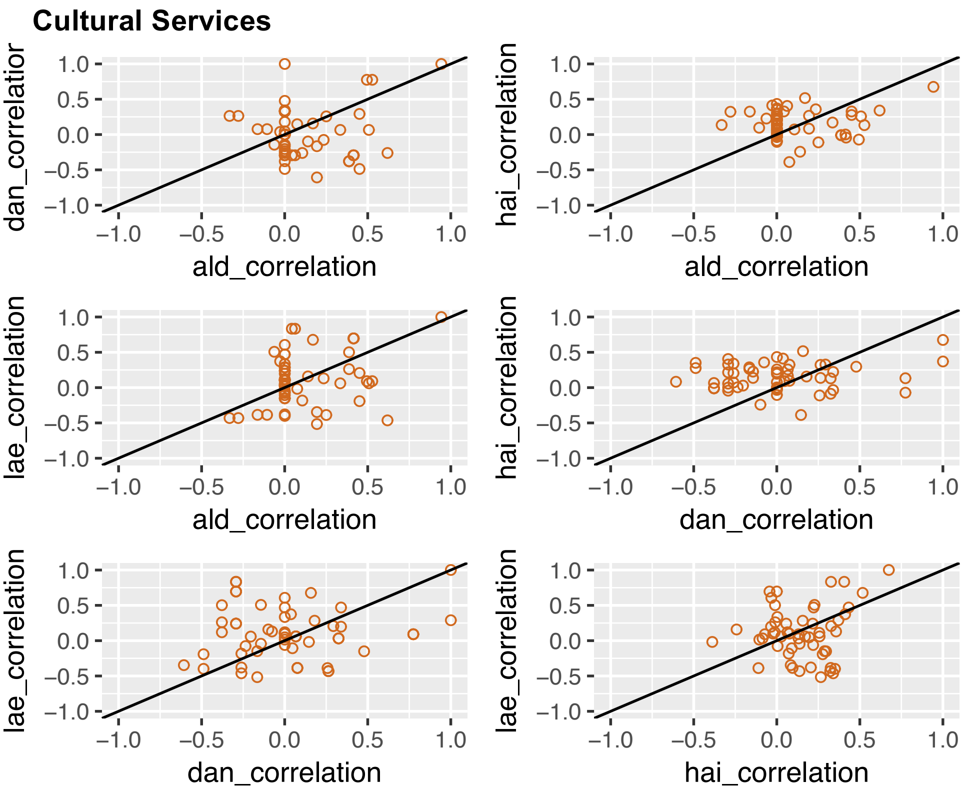

Figure 24: Scatter plots of cultural:cultural correlation scores between sites. Ald= Aldabra; dan = Danum; hai = Haibei; lae = Laegern.

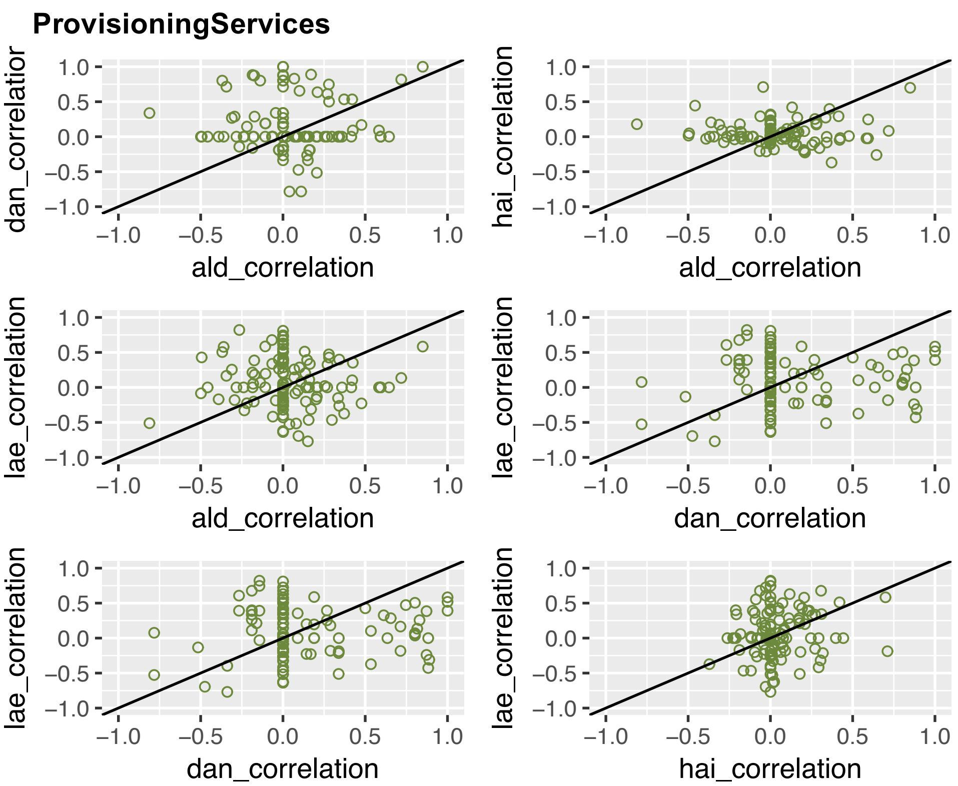

Figure 25: Scatter plots of provisioning:provisioning correlation scores between sites.

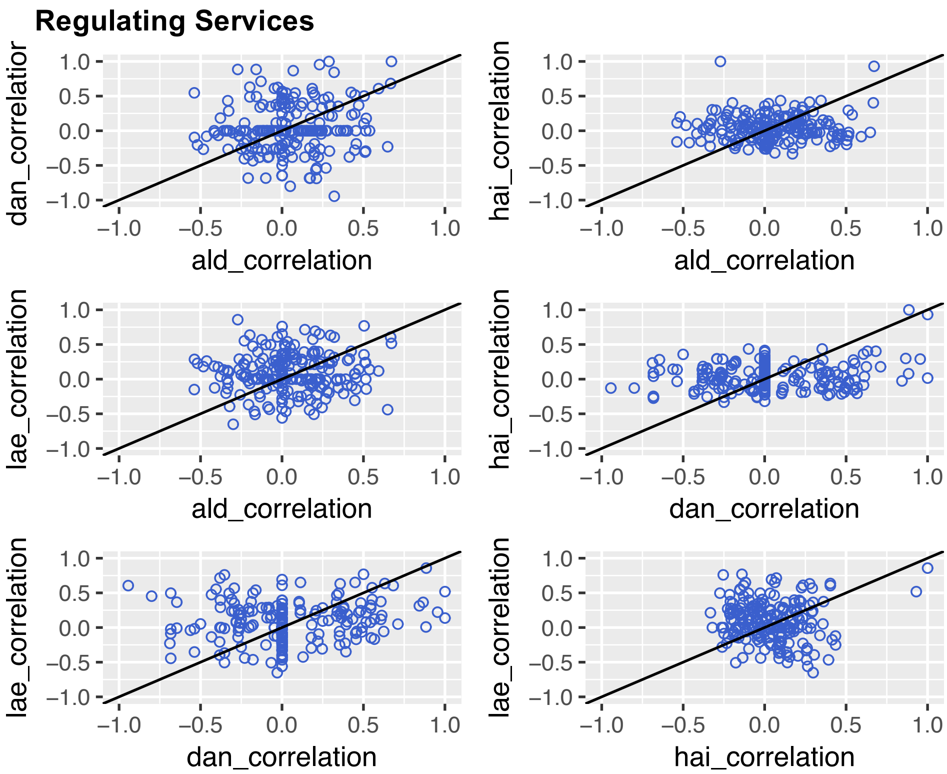

Figure 26: Scatter plots of regulating:regulating correlation scores between sites.

The same analysis with site and pooled data (figure 27), shows very different patterns. Points are widely spread around the 1:1 line, suggesting dissimilarity between the sites and the full data set. This illustrates that, while pooling data may be of value, this dataset is not representative of perceptions of ecosystem services at individual sites.

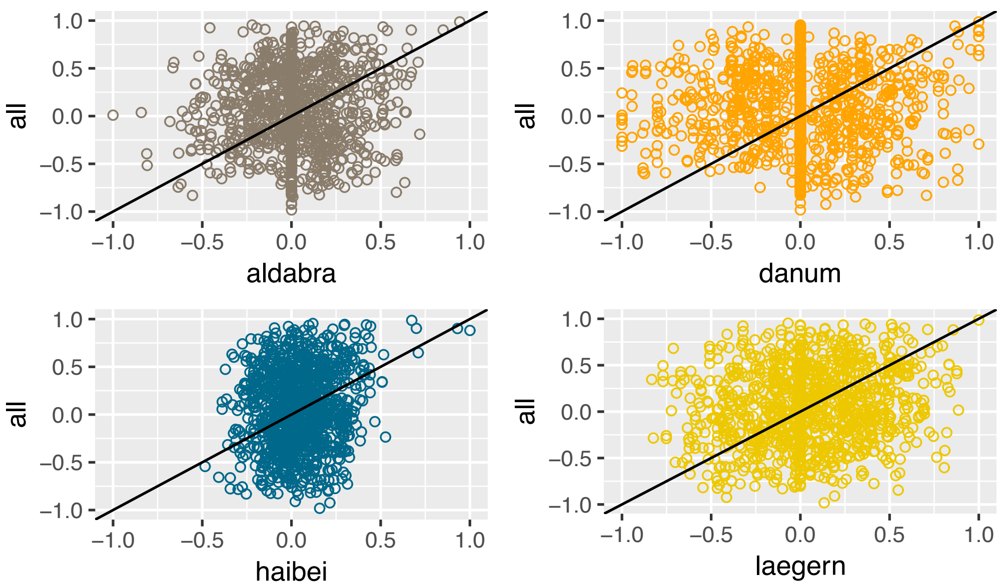

Figure 27: Scatter plots of all service scores from pooled (all) data, with site data.

Mantel Tests

In all cases the mantel statistic was very low (0.025 to 0.081), suggesting that there are very weak correlations (or similarity) between the ecosystem service correlation patterns at each site.

Aldabra:Danum		Aldabra:Haibei	
Mantel statistic r:	0.02499	Mantel statistic r:	0.05222
Significance:	0.189	Significance:	0.045
Aldabra:Laegern		Danum:Haibei	
Mantel statistic r:	0.08145	Mantel statistic r:	0.05081
Significance:	0.011	Significance:	0.051
Danum:Laegern		Haibei:Laegern	
Mantel statistic r:	0.02886	Mantel statistic r:	0.04436
Significance:	0.155	Significance:	0.099

I ran the same test with the pooled data with very similar results. That is, the test statistics are low suggesting weak or no correlations.

Pooled data: Aldabra		Pooled data:Danum	
Mantel statistic r:	0.06335	Mantel statistic r:	0.01656
Significance:	0.033	Significance:	0.244
Pooled data: Haibei		Pooled data: Laegern	
Mantel statistic r:	0.1403	Mantel statistic r:	0.1614
Significance:	0.001	Significance:	0.002

3.5.2 Networks

While correlations show pairs of services that may go together in people's perceptions, it is perhaps more useful to look at services that correlate positively, or negatively, with multiple other services. This allows us to discern whether there are groups of ecosystem services that are either related or unrelated in people's perceptions. The network maps of the full data set give some indication of what these bundles might look like.

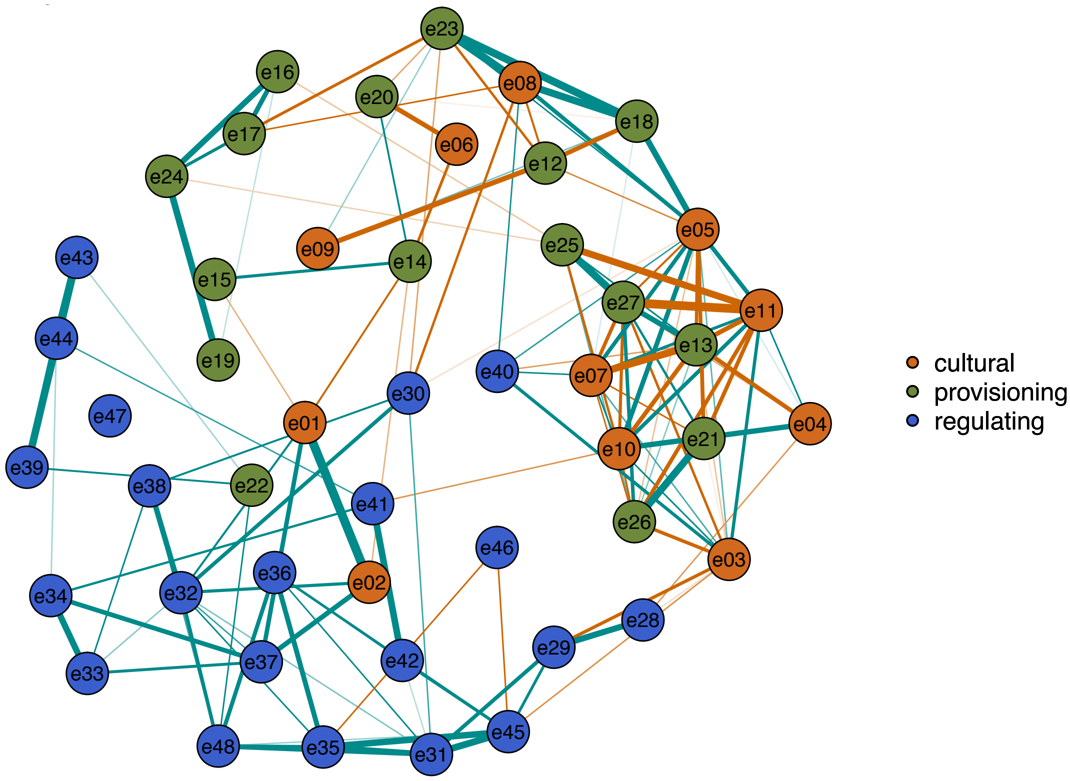

Figure 28: Network of correlation matrix for full dataset. Shows correlations below -0.65 and above 0.65. Line weight indicates strength of the correlation.

Figure 28 above indicates groups of relationships between ecosystem services. As this analysis uses the two-way correlation matrices to calculate the network, there are similar patterns that are expanded from the service pairings. Consequently, figure 28 shows some strong positive relationships within the sections, especially within the regulating services, and weaker but positive links within cultural services. However, provisioning services have both positive and negative relationships with each other, and with services from other sections. There is a cluster of a number of cultural and provisioning services (3, 4, 5, 7, 10, 11, 13, 21, 25, 26, 27), showing a pattern of negative relationships between agricultural activity (reared animals, animal and plant based resources) and less specific cultural uses (heritage and aesthetic values). The regulating service 40 is also connected to this cluster, linking positively to cultural services (3, 5, 7, 8), and negatively with service 13 (reared animals). The positive connections link a number of ecosystem processes that might be expected to be inter-related, such as regulation of hydrological cycles (35), stabilisation of erosion rates (33), filtration by ecosystems (30), and mediation of noise and visual impacts (32). One service, global climate regulation (47) has no connections to any other services, at the 0.65 threshold. As with the correlation matrices, it is possible for services that are not present to be included, since their absence may be perceived as a consequence of the presence of other services.

The networks of correlations between perceptions of ecosystem services for each site are very different than for the full dataset. Visual inspection reveals some patterns that might be expected in the individual systems. Haibei is not included as no correlations are ±0.3 (figures 29-35).

There are no clear clusters of correlations for Aldabra (figure 29, below) and the regulating services appear to be evenly distributed through the network. The services with no links to others are either not present (13, 16, 27, 32), or they are not related to other services in people's perceptions (3, 10, 11).

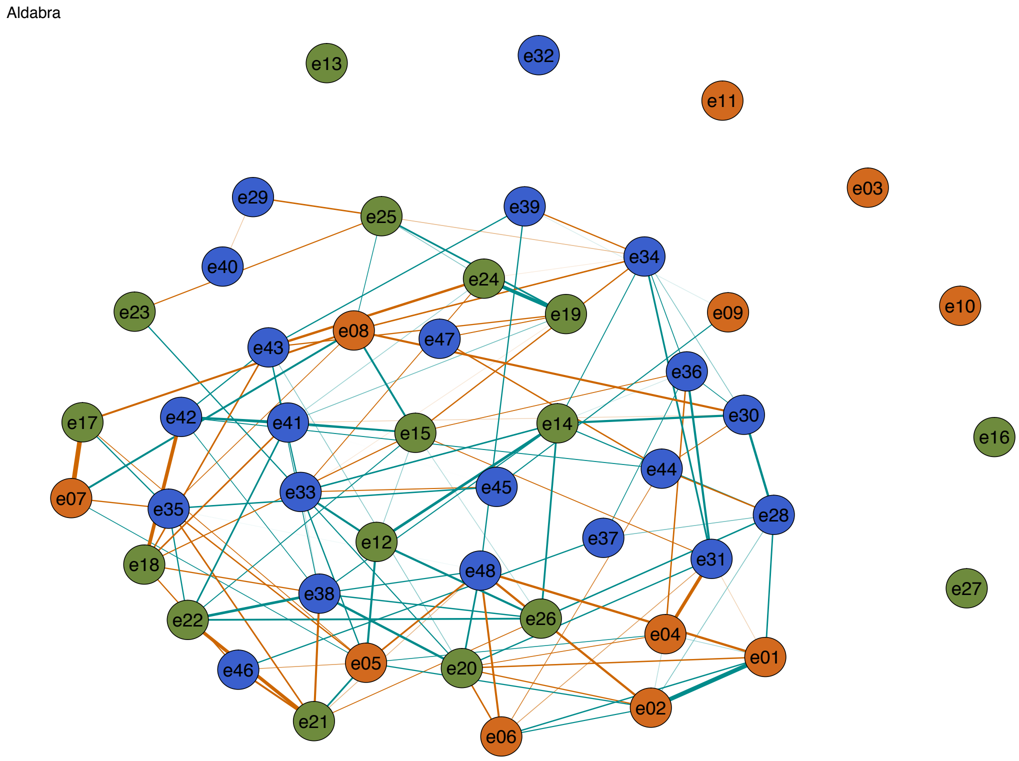

Figure 29: Network of correlations for Aldabra, showing all correlations ±0.4. Line weight indicates strength of the correlation. Services that are not perceived to be present at Aldabra = 9, 13, 14, 16, 17, 19, 20, 21, 24, 25, 26, 27, 29, 30, 31, 32, 34, 35, 36, 37, 38, 41, 42, 45, 46, 47

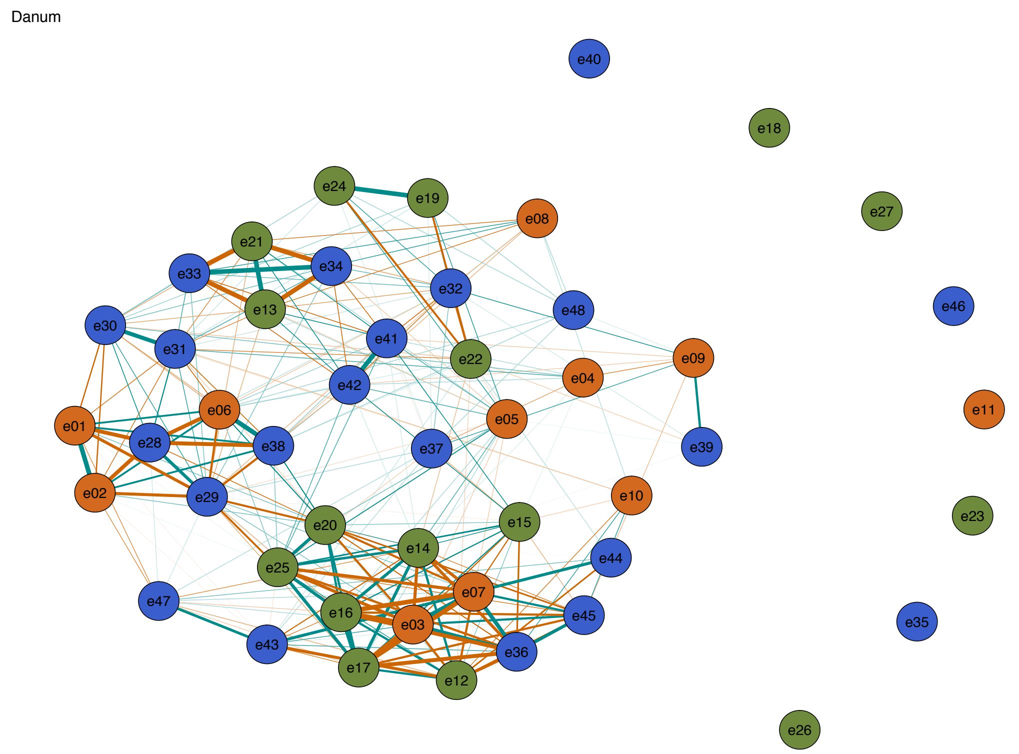

Figure 30: Network of correlations for Danum, showing all correlations ±0.4. Line weight indicates strength of the correlation. Services that are not perceived to be present = 12, 13, 15, 16, 17, 19, 20, 21, 24, 25, 26, 27, 28, 37, 46.

The network for Danum (figure 30, above) has a cluster of services that are linked, or correlated, both positively and negatively. The provisioning services in this cluster are related to aquaculture and the use of forest materials, and are not perceived to be present at the site. The network shows negative correlations with services that regulate water and soils, as well as two cultural services. Of the eight isolated services, only one is not perceived to be present at the site.

There seems to be a loose cluster of positive links between a mix of services from all three sections in the Kytalyk network (figure 31, below; services 3, 8, 11, 15, 20, 40, 47, 48). Another small cluster is between services that interviewees do not perceive to be present (25, 28, 29, 30, 31, 43). Services that are not linked to the network are all absent from the site, except for surface water for drinking and non-drinking purposes (18 and 23).

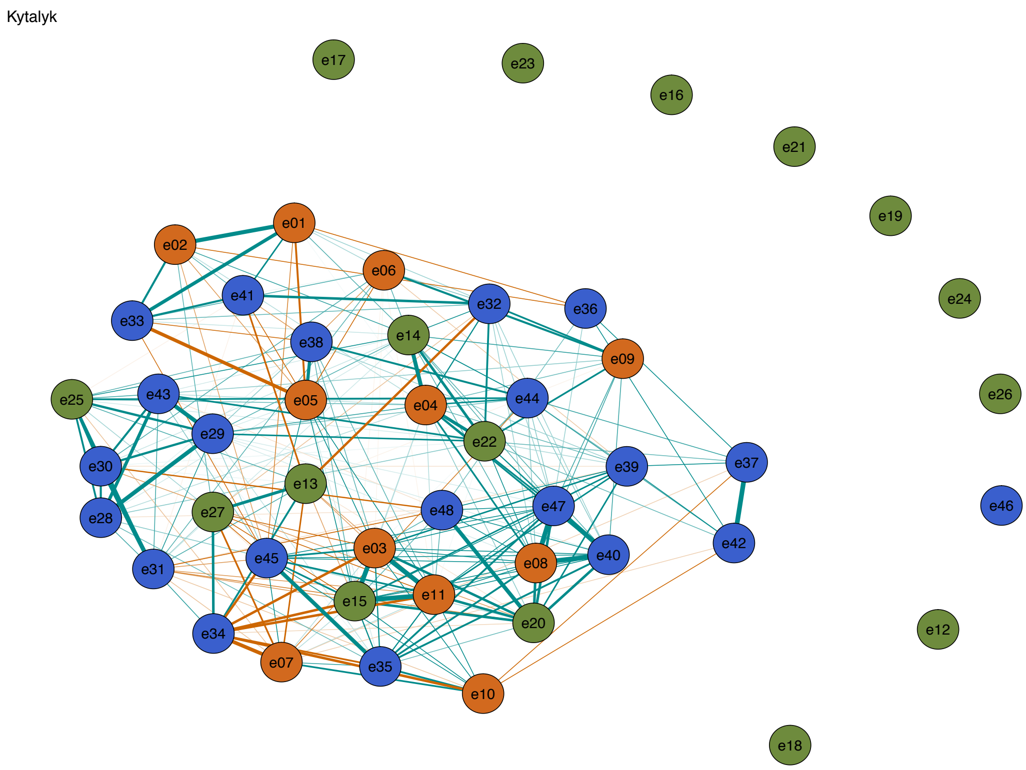

Figure 31: Network of correlations for Kytalyk, showing all correlations ±0.4. Line weight indicates strength of the correlation. Services that are not perceived to be present = 12, 16, 17, 19, 21, 22, 24, 25, 26, 27, 28, 29, 30, 31, 32, 33, 34, 36, 37, 41, 43, 44, 46.

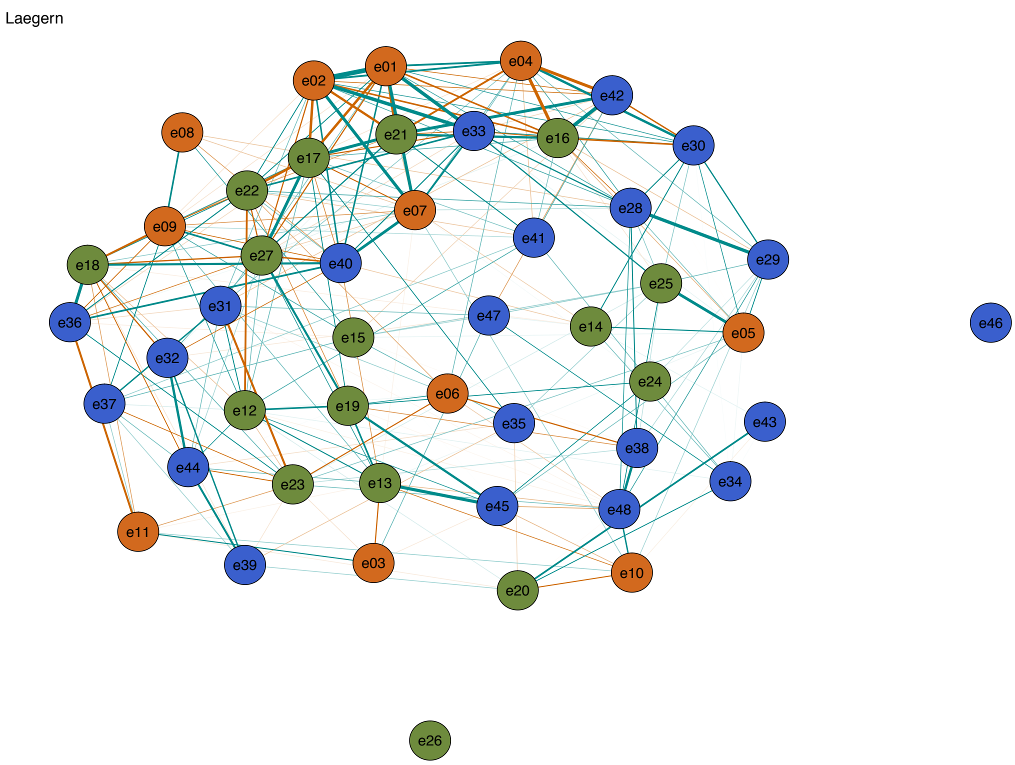

Figure 32: Network of correlations for Laegern, showing all correlations ±0.4. Line weight indicates strength of the correlation. Services that are not perceived to be present = 8, 9, 13, 16, 17, 18, 19, 21, 23, 24, 26, 27, 31, 36, 37, 41, 42, 43, 45, 46.

The Laegern network (figure 32, above) shows some positive and negative connections between provisioning services that are not provided by the site (16, 17, 21, 27) and a number of cultural and regulating services that are present (1, 2, 7, 33, 40). The correlations between the present services are positive. The two unconnected services are both perceived as absent from the site.

There are no clear clusters or groups of services at Lambir, figure 33, below). The three provisioning services outside the network are absent from the site, while the two cultural services are perceived to be present.

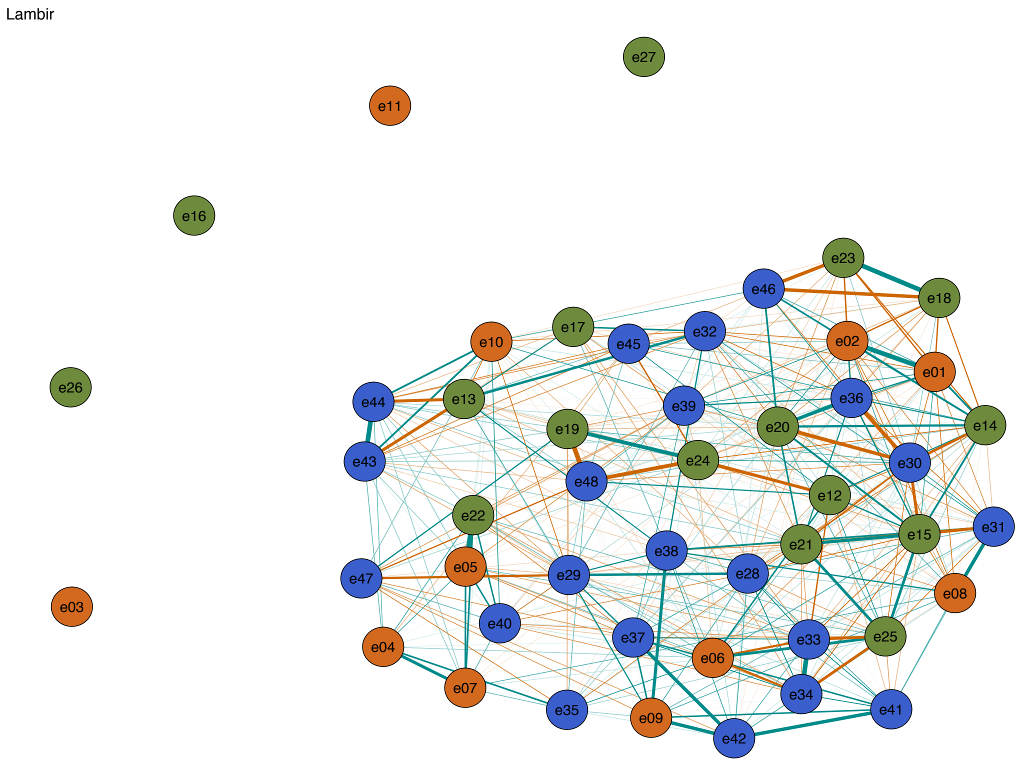

Figure 33: Network of correlations for Lambir, showing all correlations ±0.4. Line weight indicates strength of the correlation. Services that are not perceived to be present = 9, 16, 17, 19, 20, 21, 24, 25, 26, 27, 37, 41, 42, 46.

For Pasoh (figure 34, below), there is a cluster of regulating services, many of which are not perceived as present and that appear to be positively correlated. Many of these connect either positively or negatively to service 24 – ground-water for non-drinking purposes. This service has a number of positive connections to services related to producing plant material and to providing habitat, while a the same time it is negatively linked to weathering processes, erosion control and a number of cultural services. Service 11, bequest value, stands alone, and the three other unconnected services are not present.

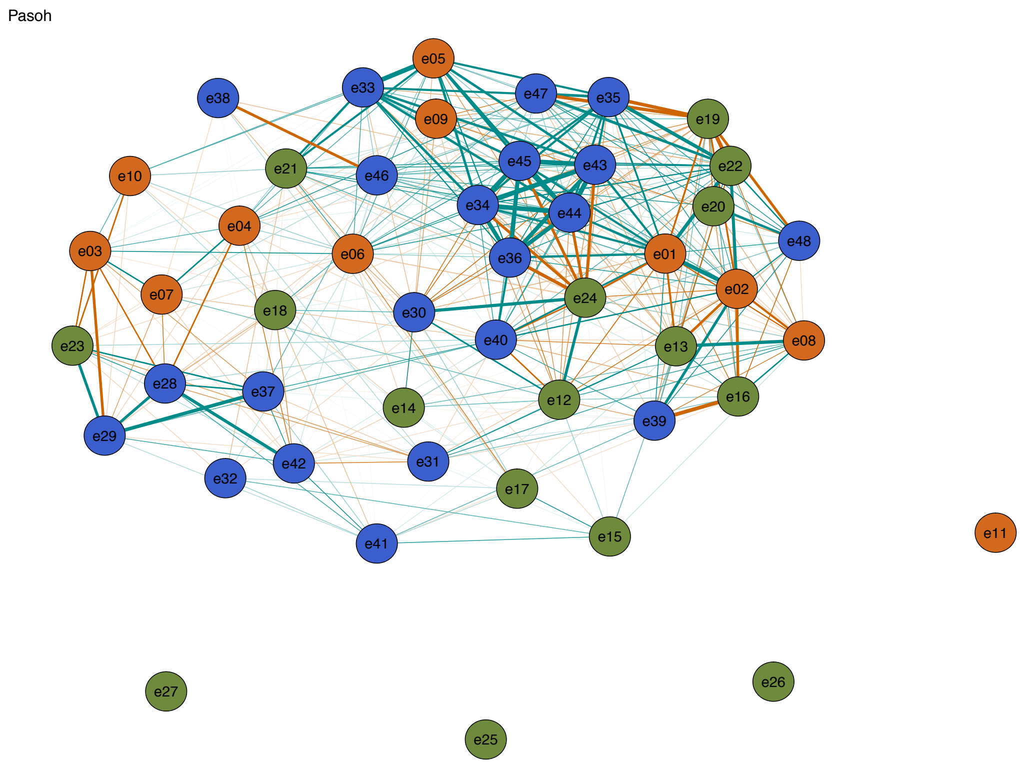

Figure 34: Network of correlations for Pasoh, showing all correlations ±0.4. Line weight indicates strength of the correlation. Services that are not perceived to be present = 8, 9, 13, 16, 17, 18, 19, 21, 23, 25, 26, 27, 28, 29, 31, 32, 33, 34, 35, 36, 37, 41, 42, 45, 46, 47.

For Lake Zurich (figure 35, below), there is a clear cluster of provisioning and cultural services, with services related to water provision being positively connected to each other but negatively with aquaculture (16, 17 and not present). Recreational and aesthetic services are also positively linked to water provisioning. With the exception of service 11, all the unconnected services are not present at the site.

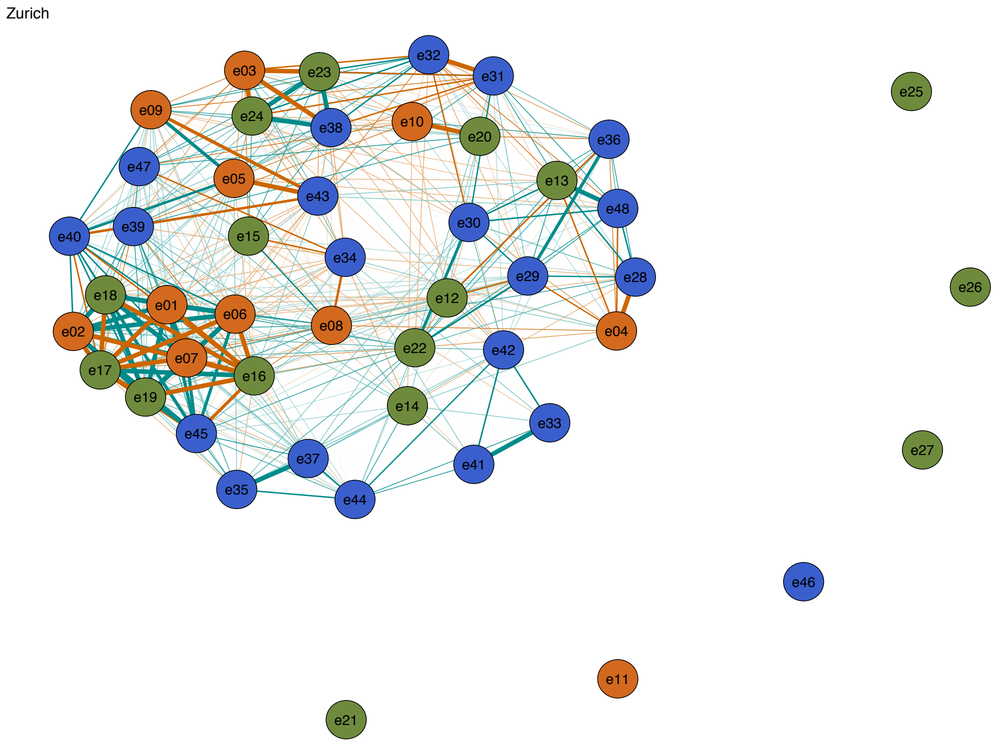

Figure 35: Network of correlations for Zurich, showing all correlations ±0.4. Line weight indicates strength of the correlation. Services that are not perceived to be present = 9, 12, 13, 14, 15, 16, 17, 20, 21, 25, 26, 27, 33, 34, 37, 41, 42, 43, 44, 46, 47

4. Discussion

This study differs from many other assessments because it is an assessment of how experts in research and management understand the ecosystem service concept. Consideration of these perceptions is critically important, in part because experts – at multiple levels – inherently have some power over how information is used and, in conservation planning, how places are managed (Berbés-Blázquez et al., 2016). By interacting with this group, I already have indications of where research and peoples' perceptions are or are not aligned, within a group of individuals responsible for deciding research directions. Effecting change is contingent on understanding and working with the diverse viewpoints of individuals (Primmer and Furman, 2012), and the study could be enlarged to show more viewpoints, I provide an indication of how broad those viewpoints could be if more beneficiaries were included. I also show important ecosystem services at research sites, and points of uncertainty within this much smaller sample of expert individuals. If further ecosystem service research is carried out at any site included here, this work indicates future directions, including potential areas of disagreement. It additionally provides indications of other beneficiaries who should be included in further ecosystem service or ecosystem management research at the sites included here.

Ecosystem Services Across Landscapes

This study has implications for consideration of service supply across landscapes and conservation planning. The type of landscape dictates the suite of services provided and we could ask how many sites are needed for the supply of all ecosystem services? In addition, are there sites that are necessary and others that are not? Not all sites have the potential to provide all services and not all services are required from all sites. Large, undisturbed systems (such as Kytalyk and to some extent the wider Tibetan Plateau in this study) are providing global services such as climate regulation through CO_2 sequestration (although they are also potential sources of CO_2 and CH_4 release) in a way that smaller sites cannot (Chan et al., 2006). Others are a link, possibly a unique link, in the chain. For example, while Aldabra is perceived as essential for providing nursery habitats for a number of marine species, the direct benefit to people is limited and felt further away through the provision of species that are caught and sold (Wieland et al., 2016). The populations on Aldabra itself are only part of this supply and are therefore probably immeasurable. However, it does not mean that at some level the nursery role of Aldabra is not important in providing marine resources for people.

System Versus Person

I detected a difference in the number of services perceived to be provided by each research site, which might be expected when exploring very different ecosystems. However it is not clear whether these differences are due to the system – both ecological and social - or the knowledge and background of the interviewees. The uncertainty around services within sites might be better explained by understanding more about the characteristics of the individuals. It might be possible to discriminate between these factors by interviewing one person about several sites. In this way, we would be able to discern how different their responses were from system to system while controlling for factors related to their own background. A few of our interviewees did give responses for two or more sites, however we did not have enough data to explore this idea. Certainly there were responses from individuals that clearly related to their own research, for example, an expert in pollination was able to give detailed information about this service at one site and the importance ranking given was probably informed by their own expertise. On the other hand, I was aware that people who were experts but not in the area being discussed would be much more reluctant to give definitive responses. For example, a soil scientist was not comfortable to give a *yes/no* response about some of the cultural aspects of the site under discussion.

Cultural Services Are Everywhere

This leads me to speculate that exploring answers about cultural services would be most helpful in revealing whether the system or the individual is affecting the response. While it is possible to directly relate ecosystem properties (forested areas, watersheds, vast open space, water bodies near large cities) to particular functions and services, it is not always clear how people think about the cultural service categories as these can be much speculative and much more connected to personal habits and beliefs. Someone who rarely recognises a religious or spiritual benefit from place may never give positive responses to this particular service, for example.

It is also clear that cultural services are indeed everywhere and important. Of the few services that are always perceived to be present at our research sites, most are cultural services. This may be because cultural services are more flexible in their definitions, for example tortoises on stamps, Siberian crane dances, or gibbons on staff badges are a reflection of a symbolic service or benefit. Some cultural services are also implicit in the designation of the research sites as protected areas (existence and bequest) that are used for research (scientific and educational). It is also possible that these services reflect individual relationships with the research sites, making it easier to rate both the presence and importance of the benefit that people perceive. Consequently, this poses a question about how we can adequately describe and measure cultural services. Arguably, this data indicates that it is enough to assume that any location will be perceived as culturally important, either because it is a protected area, contains sacred sites, is a hotspot for biodiversity, is a repository of traditional practices, or is beautiful, for example. Unless ecosystem service assessments are focussed on the specifics of a place's cultural importance – which traditional practices, how many recreational visits, types of wildlife being watched and why – there must be an assumption that people will have connections and values that go beyond measurable biophysical processes. This data also shows that this is regardless of biome, regardless of diversity and regardless of population density.

Regulating Services Are Uncertain

On the other hand, regulating services, which largely describe the biophysical processes of the system from which human societies benefit, are much less tangible. This appears to generate more uncertainty about how and whether people 'see' them. These are services wrapped up in the terminology of processes such as filtration, bio-remediation and buffering. Distinguishing between the different levels of filtering and bioremediation was difficult for interviewees and these services were often conflated with one another, as shown in their interconnections in the network analyses. Also, while the process itself might exist, interviewees were less certain that it was specifically providing something for people. Ultra-thin soils on Aldabra are certainly the result of weathering and decomposition, however it is unlikely that these are providing a direct benefit to people. It is also possible that the scale of the service itself (hydrological cycles, carbon storage, storm protection and flood control) is at a level that is too vast for individuals to have confident estimates of where it is or how much it is doing. The results indicate more certainty around regulating services that have discernable components, such as sea grass beds used by sharks as nurseries, or bee and bird populations seen to be pollinating plants and spreading seeds.

Finding ways to better describe each process at a site specific level may have revealed more certainty, or it may also be that some these functions are so closely connected that defining them as different services is not necessary. Since the network analysis also indicated positive relationships between perceptions of sites providing habitats for nursery populations and four cultural services – scientific, heritage, aesthetic and symbolic – possibly there is a less biophysical and more descriptive way to define some regulating services.

Provisioning Services Create Conflict

I found that applying techniques used for trade-off analysis to perception rather than biophysical data yielded similar results to those found in other studies (Raudsepp-Hearne et al., 2010; Howe et al., 2014). I detect generally positive relationships between cultural services, and a more mixed picture for provisioning and regulating services. I would suggest that these findings appear to reinforce the idea that provisioning services more consistently preclude other services, although clearly in this work, provisioning services are limited at all sites as they are protected areas. Our data suggest that for many interviewees, if a site was protected, it was unable to provide for material needs, including crops, timber and animal products. Where these services were perceived to be present it was either from land around the edges of the system (Laegern, Danum), because there were provisions to allow traditional practices to continue (Haibei, Kytalyk), or because the site was fundamental to providing the service within or outside its boundaries (Lambir, Danum, Laegern, Zurich).

Certainly, the most negatively correlated relationships are between services that involve extraction of natural resources (energy, reared animals and crops, drinking water, and wild plants) and cultural use or relationships with the research site. This is interesting because I anticipated correlations between, for example, the collection of wild plants and animals, and heritage or symbolic values. In fact those relationships don't appear to be present and may even be negative, as highlighted also through the network analysis. More focussed work on some of these relationships might reveal closer connections, especially in cases where collection of wild food, for example, is not legal, reducing both the activity and willingness to discuss it. It is however important to be aware that these are only 2-way relationships and are unable to reflect the full complexity of links between services.

Site Context

Looking at each site, the lack of services that are limited to one site suggests that despite their individual differences, no one service necessarily characterises each site. There is the possible exception of the use of animal based resources at Haibei, where domesticated yaks are very much part of the landscape and way of life for people who live there (Raudsepp-Hearne et al., 2010; Howe et al., 2014). This may indicate that all sites have the potential to provide a large number of ecosystem services, reflecting, from an anthropogenic perspective, basic human needs do not differ greatly across regions – every person requires at least food and shelter. The ways in which these needs are met may differ but this does not itself change the ecosystem services that people depend on, and in fact create themselves from the systems they inhabit.

However, at each site, there are some services that clearly important, that are easily described and tangible for people who have direct personal experience of them. For each site most cultural services are present, with some variation in how important they are. However, different groupings of present and important provisioning and regulating services seem to reflect well important aspects of each ecosystem. It is unsurprising that surface water is important for people who work on a coral Atoll in the Indian Ocean, where freshwater is severely limited for part of the year. The provisioning of wild food in the Arctic tundra for small, isolated human populations is to be expected, and it is equally encouraging to observe in this data clear perceptions of the importance of the role of forest systems in providing ventilation, maintaining hydrological cycles and moderating at least regional micro-climates. The one water body included here also shows clear positive perceptions of its role in providing a suite of water services to the population of Zurich.

This supports the approach of bundling not only ecosystem services but also ecosystem service perceptions to understand the wider patterns of relatedness at each research site. In this study these are very different, as illustrated by the correlation matrices, the mantel outputs and the network analyses. For example, scientific benefit receives a similar scoring pattern to aesthetic benefit but a very different one to aquaculture at Danum (there is no aquaculture at Danum, while scientific and aesthetic benefit are seen as equally important at this site), while at Haibei it is negatively related to materials for agricultural use and plant-based resources. These differing patterns suggest that we should be extremely cautious when making generalisations about perceived relationships between ecosystem services. That the site patterns are significantly different from the full dataset supports the importance of considering site context. The type of service (drinking water, cultural heritage, climate regulation) does not predetermine the other services that it occurs with, at least in people's perceptions.

It is not therefore possible to make general assumptions about how services bundle when decontextualized from site. Consequently, when considering any work on ecosystem services, generalized models (frameworks) (bundles/trade-offs and synergies) must be considered with caution. Site context appears from this to be more important, certainly in the perceptions of people who live and work at the sites.

Sampling Perceptions

This also emphasises the importance of gathering perception data, as measures of function (supply) are not necessarily measures of service use (demand). While perceptions may be inherently inaccurate, they may in fact be capturing actual use information rather than potential supply. And this is important when making the distinction between functioning and services. To better quantify this, further work that compares biophysical data about supply (or functions) with perceptions data would reveal where data converges and diverges.

It is important to note how few interviews (7-10) were required to produce saturating curves that captured most of the perceived ecosystem services for this group of interviewees. It may have been better to include Pasoh rather than Danum, since the data appears more reliable despite the lower number of interviewees. However, the curves for all sites approach asymptote. If we consider that perceptions are important and can provide working baselines for ecosystem service assessments, it is very important to know that large numbers of interviews are not necessary. Collecting qualitative and quantitative interview data from a representative group of interviewees can be relatively straightforward, with these interviews adding important information to other ecosystem service data which may give guidance towards areas for further enquiry. This includes having a much wider and more representative selection of interviews, as this was a selective group of interviewees. It is important to emphasise that there are always ‘invisible’ groups and individuals in any ecosystem services work.

Chapter 2

Sources of Uncertainty and Disagreement in Perceptions of Ecosystem Services

Anticipated journal submission:

Journal: PLoS ONE

First Author: Katherine Horgan

Contribution: 75-90% (conception, fieldwork, analysis and writing)

Abstract

Ecosystem service assessments are gaining traction for providing information about the state of ecosystems and society's dependencies on them. Understanding how those services are perceived by the people who live and work in the ecosystems providing them, and how those perceptions differ, is helpful in providing more nuanced, informed and actionable information to decision makers. I interviewed 103 selected experts working at eight research sites about their perceptions of ecosystem services at those sites. I recorded a number of attributes about each individual and used this information to test whether particular attributes explained variation in responses about the presence and importance of ecosystem services. Pooling data from all research areas obscured the effects of individual attributes. However, selecting services at each site that elicited uncertain - *I don't know* – responses, or services where interviewees disagreed - *yes* or *no* - responses, revealed some common attributes. In general, interviewees who live locally to the site, rather than those who were visitors, gave more certain responses about ecosystem services, as did people with more experience of the research sites. For services that elicited opposing responses from groups of individuals, I found that in some cases, men and women, people with different occupations, and people of different ages showed tendencies to disagree. However, there were different site-specific patterns in both the types of services that elicit uncertainty and disagreement, and the individual attributes that may account for them. Consequently, I suggest that while perceptions of ecosystem services that are both uncertain and disagree are essential for identifying gaps in knowledge and potential conflicts, generalisations about uncertainty and disagreement related to ecosystem services should be cautious. The biophysical and socio-political context of each area being assessed is unique and will yield site and system specific results that are difficult to scale-up to broader definitions of ecosystem services. This is important in the context of eliciting and including different kinds of knowledge in future ecosystem service assessments, including those produced by and IPBES (Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services).

1 Introduction

1.1 Ecosystems and the Services They Provide

In his 1935 paper critiquing the terminology employed at the time to describe successional vegetation, ecologist Arthur Tansley, described the ecosystem as:

> *"…the whole system…, including not only the organism-complex, but also the whole complex of physical factors forming what we call the environment of the biome… It is the systems so formed which… are the basic units of nature on the face of the earth… there is constant interchange of the most various kinds within each system, not only between the organisms but between the organic and the inorganic. These ecosystems, as we may call them, are of the most various kinds and sizes. They form one category of the multitudinous physical systems of the universe, which range from the universe as a whole down to the atom."* (Tansley 1935, pp.299-300)

A later, more succinct definition comes from Begon, Harper and Townsend:

> *"the ecosystem…comprises the biological community together with its physical environment."* (Begon, Harper, and Townsend 1996, pp. 679)

Ecosystem size is open to interpretation (Sayre et al., 2014) although broadly, Tansley suggests that it can be delineated largely by climate and soil, which together influence and are influenced by the particular assemblages of plant and animal communities of the biome. Biomes are *"…the whole webs of life adjusted to particular complexes of environmental factors"* (Tansley 1935, pp. 297). He stresses that ecosystems are not fixed or stable; *"…ecosystems are extremely vulnerable, both on account of their own unstable components and because they are very liable to invasion by the components of other systems."* (ibid., pp. 301)

While this original discussion forming the ecosystem concept focused on natural systems and their climax communities, Tansley recognized the importance of human activity within those systems. This is in relation to delayed or interrupted successional stages, through grazing regimes, for example. Even in this early phase of ecological research, he was critical of ecologists ignoring human interventions in natural systems. It is a nod to the need to acknowledge that humans are part of ecosystems and consequently are dependent on them.

It is a short step then to the emergence of the ecosystem services concept (Ehrlich, 1970; Schumacher, 1973; Costanza et al., 1997; Daily, 1997), although the idea of human dependency on nature is by no means a new one. The history of its development has been more thoroughly outlined elsewhere (Gómez-Baggethun et al., 2010) but in essence, as humans are also components of ecosystems, they are fundamentally dependent on the resources and functions of those systems. The resources we require are multiple, examples include fresh water; land to grow crops and provide food; timber and other materials for constructing shelter, and for fuel. Ecosystem functions that contribute to our survival and well-being range from cycling carbon dioxide and oxygen to provide breathable air, to filtering toxins, to regulation of hydrological systems.

More specific definitions of ecosystem services have typically categorized our dependencies into three (sometimes four) broad classes (Boyd and Banzhaf, 2007; Haines-Young and Potschin, 2012). Provisioning services encompass the extraction and use of resources; regulating services are the ecosystem functions contributing to human life, as outlined above; supporting services, are, for example biodiversity that underpins all other services; and lastly cultural services, that provide benefits such as aesthetic enjoyment, recreational and educational opportunities, and spiritual inspiration from nature.

Definitions for discrete ecosystem services are subject to constant revisions, for example the Common International Classification of Ecosystem Services (CICES) framework can be updated, and has had two versions between 2012 and 2017 (Haines-Young and Potschin, 2012, 2018), while the work of IPBES, and multiple national ecosystem service assessments, continue to provide additional detail for clearer, more precise definitions and indicators for ecosystem services and benefits (Seppelt et al., 2012; Maes et al., 2013; ECNC, 2017; European Commission, 2017; IPBES, 2018).

IPBES has invested considerable effort in reassessing the terminology of ecosystem services, developing a framework, amongst the plethora of ecosystem services conceptual frameworks (World Resources Institute, 2003; Fisher et al., 2009; Haines-Young and Potschin, 2013; Maes et al., 2013; Mace et al., 2015), that considers other ways of understanding and relating to nature (IPBES, 2012; Borie and Hulme, 2015; Díaz et al., 2015a). Most recently, the platform has adopted the term *Nature's Contribution's to People*, in preference to *Ecosystem Services* (Díaz et al., 2018). The variability in terms, definitions and use of language connected to ecosystem services illustrates well why individual perceptions of human dependency on nature differ. However, the essence of the concept remains that human life on earth is dependent on healthy, functioning ecosystems. If those system are degraded, so is their ability to support (human) life (Cardinale et al., 2012; Folke et al., 2016).

1.2 Growing Concern for the Sustainable Delivery of Services

The degradation of ecosystems that impacts their ability to function and support life (Isbell et al., 2015b) is, from a human perspective, a cause for concern (Rockström et al., 2009). For example, if hydrological systems are so degraded that they are unable to regulate water flow and prevent downstream flooding of people's land and homes, this is a problem (Gao et al., 2017). The very real impacts of degraded systems on human livelihoods underlie the need for sustainable approaches to how we manage the environments that we depend on. Sustainable practices are not new, and societies, or at least individuals, have always understood the need to conserve some resources for future survival (Carson, 1962; Buschbacher, 1990). Whether this is through storing grain for the next growing season, retaining standard trees within coppices for variable timber production, or only harvesting a fraction of the fruit from any wild growing plant (Carson, 1962; Buschbacher, 1990; Huntington, 2013; Kimmerer, 2013). However, the threats to and impacts on ecosystems from global change are increasing (Rockström et al., 2009; Barnosky et al., 2012; Steffen et al., 2015), leading to heightened concern for how to deal with these threats. A more rapidly changing climate is affecting regional weather patterns, leading to unpredictable rainy seasons, increased droughts, milder winters and more extreme weather events. Land use change is reducing and fragmenting habitats, shrinking forest areas, encroaching on watersheds and reducing connectivity between patches; while industrialization and nutrient inputs are increasing the deposition of pollutants on land and in our freshwater and marine systems. Added to these problems is increased movement of non-native plants and animals, which can become invasive and suppress local plant and animal communities. These threats are interconnected and are largely a result of human over-exploitation of natural resources.

Rising concern for the ability of ecosystems to sustainably deliver ecosystem services, and consequently support (human) life on earth, is illustrated by the growing number of international environmental agreements, conventions and platforms since the mid-twentieth century. They include:

- International Union for the Conservation of Nature (IUCN, 1948)
- IUCN Redlist of Threatened Species (1964)

- Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES, 1975)
- The Brundtland Report (UN, 1987)
- Intergovernmental Panel on Climate Change (IPCC, 1988)
- Convention on Biological Diversity (CBD, 1992)
- IPBES (2012)
- Sustainable Development Goals (SDGs, 2015)

1.3 Ecosystem Service Assessments as an Accounting Method

The need for integrated sustainability and ecosystem services science is emphasized by calls from the science-policy community for more inter-, multi-, and trans-disciplinary science that can provide guidance to the people and organisations that require it (Abson et al., 2014; Brooks et al., 2014; Bennett et al., 2015). To have a more sustainable relationship with the planet, we need more informed knowledge about natural resources; where they are, how much we have, how much is being used and by whom. We also need to predict how these stocks and flows might change in the future, including how societal demand might change. Ecosystem service assessments provide a form of environmental accounting that quantifies these current and future stocks and flows. They are one tool in working towards the goal of reaching balanced decisions about the sustainable use of natural resources, and can take an empirical approach couched in fiscal terms (de Groot et al., 2012).

While the economic focus of ecosystem service assessments has been widely criticized (see Schröter et al. 2014 for an outline of key critiques and responses to these), the fact is that society already does this for any marketable goods. For example, timber has a market price, and FAO (Food and Agriculture Organisation) records allow us to estimate how much timber is harvested annually. The same is true for agricultural production, water supply, carbon storage and fish stocks, albeit at varying scales of precision. Assessments aim to define the different scales at which resources are supplied, ranging from global (the benefits of carbon sequestration are globally distributed), to very local (wild mushrooms are gathered locally by the people who consume them). Ecosystem service assessments can be carried out at sub-global scales (IPBES Regional Assessments) but may also be site-specific. The different scales, and reasons for the assessments provide different levels of information, and offer very pragmatic guidance to those people tasked with making budgeted decisions about land use. These might be national governments deciding agricultural policies, watershed managers or organisations managing protected areas. Ecosystem service assessments also give an indication of how much an area of land is ‘worth’, both in terms of costs and of the multiple benefits it can provide, and the possible trade-offs between services.

1.4 The Role of People in Defining Ecosystem Services

Of course, none of this is straightforward (see for example the research needs outlined in (Carpenter et al., 2009) and the outputs can be imprecise; indicators for each service differ across regions and scales (Egoh et al., 2012; Mononen et al., 2016), trade-offs and synergies between services (Cavender-Bares et al., 2015) and with biodiversity (Kremen, 2005; Isbell et al., 2017) are complex and poorly understood, and there are continuing issues around how to deal with different spatial and time scales (Meadowcroft, 2002; Moore et al., 2015). These challenges are increased once we begin to include less tangible aspects of the ecosystem. Cultural services rarely fit into this rather empirical, economic paradigm, and there is on-going and extremely informative debate about how to define and quantify ‘value’ (Chan et al., 2012a; Daniel et al., 2012; Chan et al., 2016; Ament et al., 2017). There is also a great deal of work within and outside the ecosystem services community that aims to include the perceptions and knowledge of the actors in the system (Buijs et al., 2011).

However, the need to fully appreciate that when we frame research around ecosystem services we are dealing with context specific, social-ecological systems (SES) (Cumming and Allen, 2017) continues to be overlooked in some ecosystem service research (Menzel and Teng, 2009). There is large body of extremely important, detailed work focused on biodiversity and ecosystem functioning. However, studies often refer to the importance of biodiversity for ecosystem services with no direct reference to beneficiaries or the direct use of resources.

Arguably, this negates the legitimacy of referring to ecosystem services, since these are defined by human needs. Even when stakeholders, or the SES, are referenced, details are scant, as are specifics about how to integrate research into actors and social systems with biodiversity/functioning studies (Díaz et al., 2007; Quijas et al., 2012; Isbell et al., 2017). Similarly, some of the rapidly expanding work in remote sensing, allowing land-use mapping at increasingly finer scales (Sayre et al., 2014), risks quantifying ecosystem service potential, while overlooking beneficiaries.

These appear as criticisms of the research, however, it is important to emphasise the reasons for omitting stakeholder needs, perceptions of those needs and other knowledge types. The requirement to tie research directly to policy relevance can necessitate references to ecosystem services, and it is to be expected that they are at least considered, if not directly addressed, across a number of research fields. However, fully integrating research that deals with the expectations, perceptions and needs of the multiple actors in the system is extremely challenging (Abson et al., 2014). Work that very specifically includes stakeholders illustrates well why this introduces multiple levels of complexity. Apostolopoulou et al. (Apostolopoulou et al., 2012a) provide a detailed picture of the difficulties involved in actively identifying and involving stakeholders, beyond expressing a wish to engage with them on paper Saarikoski et al. (Saarikoski et al., 2018) clarify – or possibly confuse - this further by highlighting the multiple institutional challenges to integrating and operationalizing ecosystem services guidance. Amongst these challenges are building trust in the researchers, navigating conflict between actors, and changing entrenched behavioural norms Further, IPBES has consistently struggled to recruit social scientists, despite having recognized early on that ecosystem services research cannot be comprehensive without the involvement of all disciplines (Beck, 2014; Rosa et al., 2017). Redefinitions of conceptual frameworks and the ecosystem services terminology reflect the struggle to include the different approaches and methods needed to elicit people's perceptions of and knowledge about their dependencies on ecosystems.

That is not to say that all assessments lack a more complex approach; Rabe et al give a good outline of the range of approaches and assessments to date (Rabe et al., 2016). Case studies and ecosystem service assessments that are carried out at local scales and in contexts where many actors know each other, and there are sufficient levels of trust between them, are able to be much more inclusive and engage with multiple knowledge types. However, even within a research community that has limited contact with local actors, it is still possible to start this process.

1.5 Understanding Perceptions of Ecosystem Services

Although an ecosystem service assessment can aim to be an objective accounting exercise, ecosystems are not one-dimensional entities (Fisher et al., 2009). They are complex systems, co-created with people, communities and cultures. People within the system have very different perceptions of the places where they live and work. Engaging with actors to capture detailed, in-depth knowledge about how they perceive their relationships with the ecosystems they depend on, and to understand how far they are aware of these dependencies, is critical work for the ecosystem services community to be engaged in. This type of knowledge from actors adds detail, richness and elements that might be overlooked without it (Berkes, 2008; Dick et al., 2018).

It is important to acknowledge that access to all actors is not possible in all studies, and that building connections with people requires time and commitment that may not be possible within the particular constraints of the research project. Full engagement with communities requires a long-term commitment to the process, as it ultimately depends on building trust. What is essential, however, that the process is started where it can be and missing actors are acknowledged.
The following study is an example of this, where researchers and site managers have been considered as actors in the ecosystems being studied. These are people who have distinct ideas about those systems and their importance, alongside their specific research expertise. It is a biased sample of, largely, informed stakeholders and it is a limited representation of the actors in each system. However, it is also a legitimate starting point for building awareness about how selected individuals have different understandings of their, and others', dependencies on ecosystems, and what they understand by *ecosystem services*. For example, interviewees might be very clear about the recreational opportunities provided by a large body of water near a large population centre but have less clarity about the benefits provided by small bodies of freshwater on a mostly unpopulated coral atoll. Equally, some people may find regulating services to be 'invisible' or hard to define, for example, mediation of noise may only be apparent when a forest is located near to roads, although in any location it will have an effect on acoustics that may not be noticeable to most people. Finally, some people might find a spiritual benefit in the vast open space of a tundra landscape, while others find it in the ruins of an old church.

Capturing variability in perceptions, provides the richness referred to previously (Chan et al., 2012a), and creates uncertainty and disagreement about the presence and importance of ecosystem services. In this study, this led to three main research questions:

1. What might explain the overall variability in people's perception of the importance of ecosystem services?
2. Do individual attributes help to explain the likelihood that an interviewee gives a certain (or uncertain) response about the presence of ecosystem services?
3. Do individual attributes predict which groups of individuals respond *yes* or *no* about the presence of ecosystem services that have high disagreement in responses?

Understanding which services and individual attributes invite both uncertainty and disagreement in people's perceptions allows a more informed consideration of methods to reduce or account for variation. If this is in relation to characteristics of the interviewee, this supports the need to listen to a wide range of beneficiaries in ecosystem services research in order to capture a fuller picture of people's relationships with the natural environment (Berbés-Blázquez et al., 2016). Being aware of points of uncertainty and disagreement also allows us to anticipate areas of conflict between services and/or between people. This is a useful starting point for further work that has a better representation of actors, and adds to growing research that aims to integrate different knowledge types from a variety of actors, including indigenous and local knowledge (Primmer et al., 2018).

2 Methods

In this study, I investigated whether known attributes of interviewees affected their perceptions of ecosystem services. I looked at factors that might explain uncertainty in individual responses, and disagreement amongst groups of people. I collected data about ecosystem services from 103 semi-structured interviews with experts from eight research sites. In the interviews, I specifically asked interviewees for their perceptions of the presence and importance of the 48 ecosystem services listed in CICES V4 (Haines-Young and Potschin, 2012).

2.1 Research Sites

How people perceive the presence and importance of ecosystem services is partly due to specific attributes of each site, including biodiversity, geography, and spatial scales and flows of services. The eight study sites in this research cover a range of ecosystems that differ ecologically and socio-politically (table 1). The sites are located at different latitudinal gradients, in different biomes, and cover very different spatial scales. Each country has its own socio-political infrastructure that impacts the status and governance of the sites, as well as the specific circumstances, cultures and values of the people who live in and around them. These geographical, social and political differences are not specifically explored in this study but an awareness of their influence on the outputs is nevertheless important. Although all sites were used in some analyses, more detailed work was only carried out on data from two sites, Aldabra Atoll and the Qinghai-Tibetan Plateau site.

Site	Biome	Country	Size	ES	People
Aldabra Atoll	Tropical semi-humid atoll	Republic of Seychelles	155.4km^2 land in Indian Ocean	22	17
Danum Valley Conservation Area	Lowland mixed dipterocarp forest	Malaysia (Borneo)	438km^2 primary forest	33	8 (7)
Haibei Alpine Meadow Ecosystem Research Station	Alpine meadow	China (Qinghai Province)	0.06ha of Tibetan plateau. 39354km^2 in Haibei Prefecture	27	42
Kytalyk Resource Reserve	Arctic tundra	Russia	1608km^2 reserve area	24	7
Laegern Research Station	Temperate forest	Switzerland	9ha within 400ha forest area	28	11

Lambir Hills National Park	Mixed tropical dipterocarp and heath forest	Malaysia (Borneo)	6952ha forest	34	6
Pasoh Forest Reserve	Lowland dipterocarp forest	Malaysia (Peninsular)	600ha virgin forest within 1840ha secondary forest	22	7
Lake Zürich	Freshwater lake	Switzerland	88km^2 surface area	27	5

Table 1: Research sites included in this study. ES is the number of ecosystem services identified by interviewees for each site. The number of people interviewed is noted in the last column, *People*.

2.1.1 Aldabra Atoll

This is the most remote of the 115 islands that make up the Republic of the Seychelles, a sovereign state and member of international organisations such as the African Union and the United Nations (UN). The islands have been inhabited and exploited by different European nation states since the 1500s (Beamish, 1970; Stoddart, 1971), creating a young and diverse history and culture. A colonial history of exploitation has significantly impacted the flora and fauna on many of the islands (Gaymer, 1966), and successes in eradicating invasive species and preserving endemics is much fêted in the Seychelles (Seychelles Islands Foundation (SIF), 2013, 2012), as is the World Heritage status of both Aldabra and the Vallée de Mai on Praslin Island (Fischer and Fleischer-Dogley, 2008). This is significant for understanding how Aldabra is perceived locally. One interviewee for this study described it as the 'jewel of the Seychelles'. As the Republic of the Seychelles is relatively newly autonomous from foreign rule (1976 from the United Kingdom), ideas and symbols that represent that independent identity are important. Aldabra and the Vallée de Mai are managed by the Seychelles Islands Foundation (SIF).

2.1.2 Haibei Alpine Meadow Research Station (HAMRS)

HAMRS is on the Qinghai-Tibetan Plateau in China. It has a history of habitation by a large number of different settled and nomadic ethnic groups, including the Han Chinese, Tibetans, and Mongols. The importance of the Tibetan minority is reflected in the status of Haibei as an Autonomous Prefecture. Qinghai Province, while very large, has the third smallest population in China. The main population centre, Xining city, has over two million people although Haibei Prefecture has only 300,000 inhabitants. The research area is very small within the vast Tibetan Plateau, and is administered by the Chinese Academy of Sciences, while the wider plateau area comes under state and private ownership. The Qinghai-Tibetan Plateau has a major influence on regional weather patterns and is also widely used for yak herding. It is considered to have high research importance. These contrasting geographic and demographic scales can create very different perceptions of how people depend on and use the plateau system.

2.2 Interviewees

The expert interviewees were drawn from researchers within the University of Zürich Research Priority Programme, Global Change and Biodiversity (URPPGCB), and from officers and managers working at the sites included in this programme. Their expertise was determined by having at least a working association with the location.

2.3 Response Variables

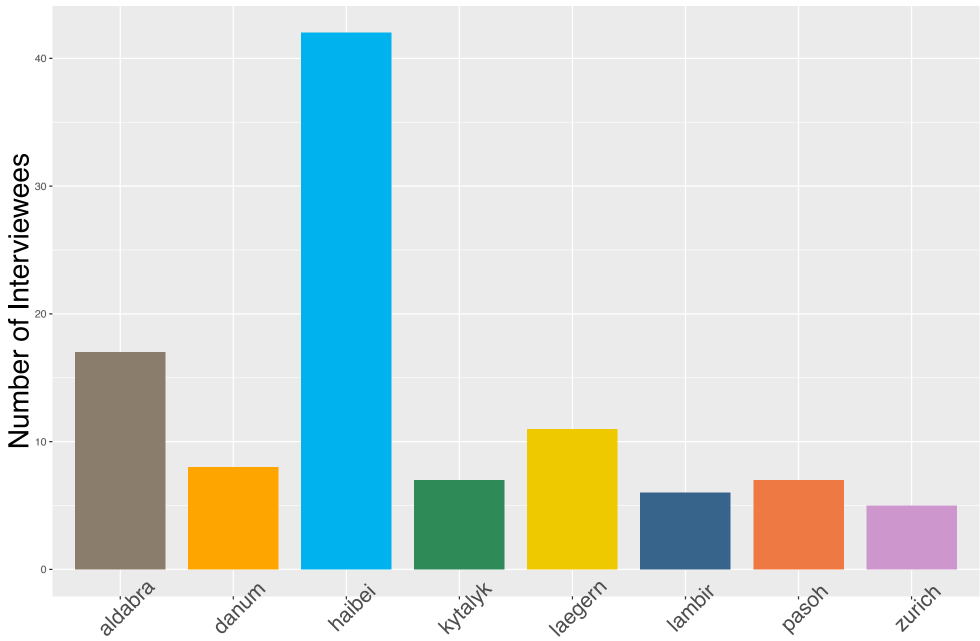

Figure 1: Number of interviewees at each research site

In guided interviews, I asked interviewees about the presence and importance of ecosystem services at a specific research site. If they responded positively about the presence of an ecosystem service, interviewees were asked to assign an importance score from low to medium (1–3).

Once NAs were removed, there were 4702 responses from a possible total of 4944 (NA=242). The number of interviewees per site was unevenly distributed, and only two sites had more than 15 individuals (Aldabra 17, Haibei 42, figure 1).

2.3.1 *Ordinal data*

Ordinal data for each ecosystem service was either 0 (not present), or from 1-3 (low-medium-high importance). *NA*s were removed. For an overall idea of the variability in interviewee responses and how to approach uncertainty, my initial analyses were with ordinal data. As there were not many interviews for most sites, I looked at the variation in ordinal responses across the full data set, and for each ecosystem service separately to control for the inherent variation in responses for each service. I pooled the data for each service from all sites, and ran linear models across the full dataset. As there is limited range in the data, I transformed the ordinal response to the inverse sine of the square root:

$$\sin^{-1}\left(\frac{\sqrt{3}}{2}\right)$$

The linear models used this as the response variable with *site* and *esv* included as explanatory variables, along with interviewee attribute variables (see below). As *site* was frequently highly significant in explaining variability in the data, I also looked at data from two sites separately, Aldabra and Haibei.

2.3.2 *Categorical data*

The categorical data is a result of recasting *yes/no* answers about the presence of ecosystem services and reflects both uncertainty from individuals and disagreement between individuals. The range of responses to the question, *"Is ecosystem service x provided by site x"*, were: *"No"* (N), *"I don't know"* (DK), *"Yes"* (Y), and *"Yes but it has a negative effect"* (YNEG). In some cases no response was given (NA), leading to five possible responses. I used these categories to determine levels of uncertainty and disagreement about ecosystem services at each site.

When interviewees are asked if a particular service is present and respond: *I don't know*, they are demonstrating uncertainty about either the service (*it might be present, it might not*), their own knowledge (*I don't really understand what this is, it's not something I have thought about or encountered before*), or both. Hence uncertainty is a property of an individual person. There is disagreement when people from one location give different responses – some may affirm the presence of a service while others deny that it is provided, leading to a mix of *yes* and *no* responses. Here interviewees are not in themselves uncertain but their conflicting responses suggest a level of confusion about the service at the research site. Hence disagreement is a property of a group of individuals around a common theme.

2.3.2.1 Uncertainty

I determined that uncertainty is evident when an interviewee responds *I don't know* to questions about the presence of ecosystem services. Using this as a starting point, I recast the categorical data into two categories. Consequently, *yes* (Y), *yes but it's negative* (YNEG) and *no* (N) indicate certainty (1) about presence or absence, while *I don't know* (DK) indicates uncertainty (0). I removed all *no information* (NA) from the data set. In order to have sufficient variability in the responses, I limited the data to only those services with a minimum DK response rate of 10%. This left 36 ecosystem services across the full data set: seven cultural 29.17%), eleven provisioning (31.52%), and eighteen (39.3%) regulating (39.3%), indicating slightly higher uncertainty for regulating services (shown with service descriptions in Appendix 4).

My preliminary analyses of the full dataset consistently showed that one site, Haibei, explains most of the variation in the data, due to the much higher number of interviewees than at the other sites (42). I therefore removed the *site* variable by analysing within sites rather than across the pooled data. To have a reasonable representation of the interviewee variables, I only used data from sites with more than 15 interviewees (Aldabra and Haibei). This gave a dataset of 51 observations of three ecosystem services (25, 26 and 46) for Aldabra, and 498 observations of 13 services (8, 9, 10, 15, 16, 17, 18, 19, 22, 36, 40, 41 and 42) from Haibei.

Initial analyses found no effect of *esv* on the responses, indicating that service type does not influence the answers given by interviewees. Having already selected services for uncertainty, I had probably already controlled for any effect of service type. As noted, the services included in this dataset are slightly biased towards regulating services as a section. Any further significant effect of *esv* is not apparent.

2.3.2.2 Disagreement

Disagreement is evident when different interviewees give opposing responses to the same question, specifically, some respond *yes* (Y) and some *no* (N). While I looked a the full dataset, I also filtered the data to services with higher levels of disagreement in responses, where at least a third of interviewees replied *yes* and *no*. This greater level of variability in the level of agreement / disagreement was needed to allow me to discern patterns in how different groups responded to the same question. I also limited the data to Aldabra and Haibei, changing the scoring so that Y and YNEG=1, and N=0, giving a dataset of 34 observations of two ecosystem services for Aldabra (35 and 41), and 353 observations of ten ecosystem services from Haibei (5, 9, 19, 20, 27, 33, 34, 36, 38 and 40). For Haibei, some of these were the same as for uncertainty (9, 19, 36 and 40). All services displaying disagreement are shown in Appendix 4.

2.4 Explanatory Variables

Throughout text *esv* represents the use of ecosystem service as an explanatory variable, and *site* refers to the discrete research site. In addition, for each of the 103 interviewees, I had eight attributes that I used as explanatory variables. These were:

ed	maximum education level (school (*sch*), college (*coll*), bachelor degree (*bsc*), master's degree (*msc*), doctorate (*phd*))
occn	occupation (academic (*acme*), management (*mgt*), site officer (*off*), researcher (*rchr*), teacher (*tchr*))
conx	connection to the site (employment (*emp*), local (*lcl*), general interest (*int*))
local	whether someone is local to the site (yes (1), no (0))
vis	whether someone has visited the site (yes(1), no (0))
gen	gender (*m*, *f*)
yexp	number of years experience of the site
age	the age of the interviewee

These variables were not evenly distributed across the interviewees (figure 2), and some attributes were not represented at all research sites. All services showing some effect of the explanatory variables are shown in Appendix 5.

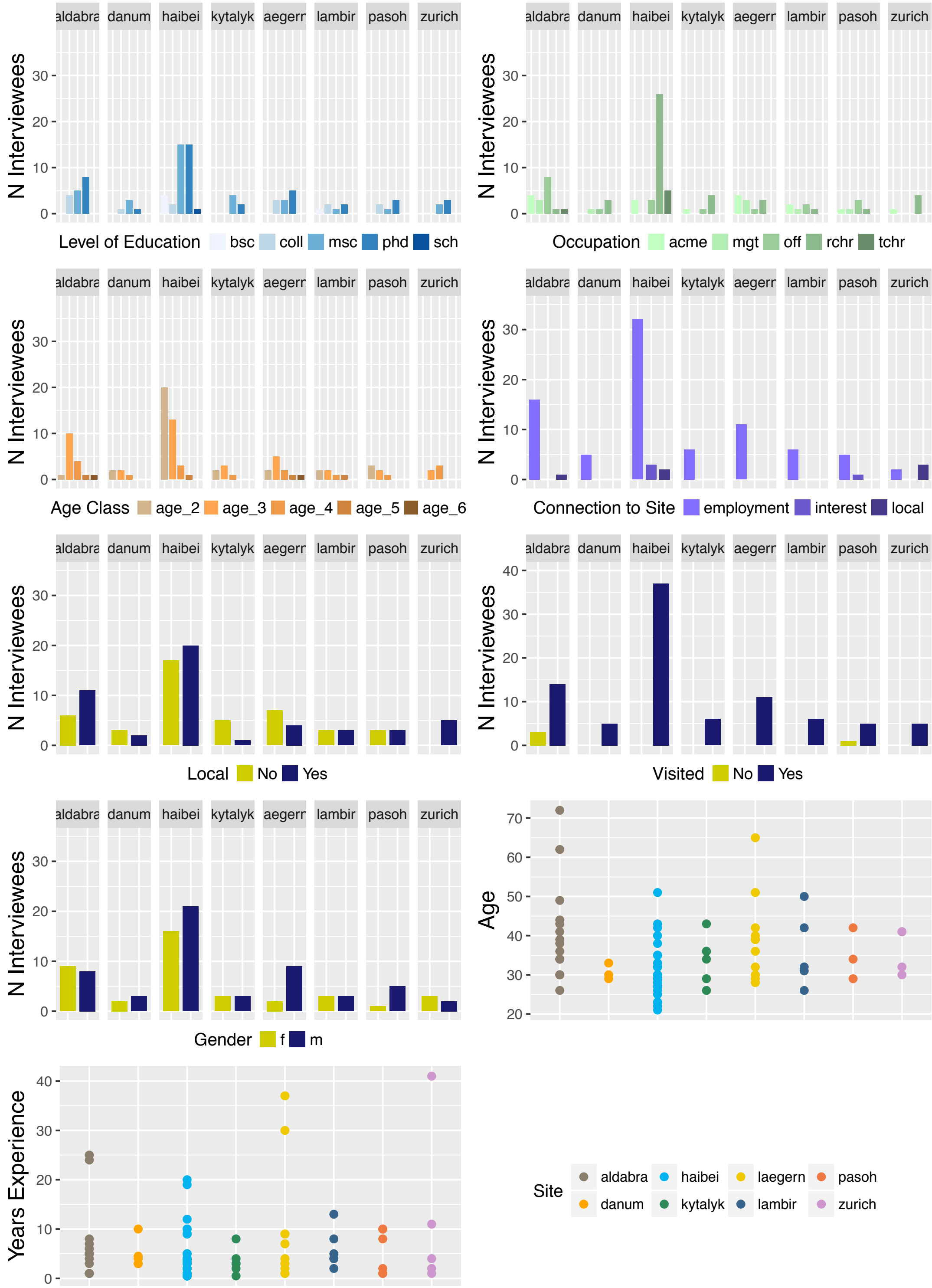

Figure 2: Distribution of individual attributes at each research site. Some attributes are not represented at all sites, for example all interviewees had visited Danum, Haibei, Kytalyk, Laegern, Lambir and Zürich; and all interviewees for Zürich were researchers or academics.

2.5 Analyses

I made linear models (lm) for the ordinal data and used analysis of variance (ANOVA) in R (R Core Team, 2016) to test for effects of all explanatory variables on the ordinal data scores for ecosystem services. My interpretations of the outputs from this dataset are tentative due to the low sample sizes and non-linearity of the data.

To analyse the uncertainty data, I used generalised linear models (GLMs), with family binomial, as I had reduced the responses to 1 (certain) and 0 (uncertain). I tested the GLMs using a ChiSq test for analysis of deviance and then calculated quasi F statistics to test for under- and overdispersion in the data. I corrected the significance (p values) accordingly. I again used R (R Core Team, 2016) for the analysis.

The disagreement data, unlike the certainty data, reflects the perceptions of the group of interviewees at each site rather than of each individual. While the same analysis as for uncertainty can be used, this simply reflects the likelihood of someone answering *yes* or *no*, not how likely groups are to disagree with one another. I therefore used classification trees to indicate attributes that might explain how groups disagree. Classification (or regression) trees recursively partition the data into sets of variables, suggesting patterns (or classifiers). They are often used as training models to classify new data (e.g. based on the responses given by person x, we can assume that this person is young, female, employed and a researcher). Ideally classification trees can partition the data to a sufficient level of certainty to be able to either predict the responses someone with a defined set of attributes would give, or to identify characteristics from the responses given. I used the rpart package in R (Therneau et al., 2017) for these analyses.

3 Results

3.1 Variability in Ordinal Data

I initially approached variability in the data by analysing the complete ordinal dataset, using linear models and analysis of variance. The full model, which included *site* and *esv*, as well as person attributes as explanatory variables, consistently found significant effects of *site* and *esv*. However, inspection of the model plots showed non-linearity and non-normal distribution in the data, with numerous repeated measures, specifically of interviewee attributes for each ecosystem service at each site. Reducing one level of complexity by removing *site* as a variable was possible but non-linearity persisted, as did repetition of the interviewee attributes. Although all analyses show a significant effect of *esv*, multiple variables were dropped from the model, probably due to the repeated measures in the data. I was able to reduce the data to the two sites with more than 15 interviewees (Aldabra and Haibei), and detect some small effects of person variables. For Aldabra, all services were given a score by at least one person, except 13, 16 and 27 which were therefore absent. For Haibei, this was the case for services 16 and 17.

3.1.1 Aldabra

To test for effects of person attributes and site I first ran all possible sequences of an additive linear model, with each variable as the first and the last term. This allowed me to find terms that are significant in both positions. The model with *local* as the only explanatory variable was the only one to indicate an effect on the response data. This model suggests a slight negative effect of being local on perceptions of the importance of ecosystem services in general on Aldabra (table 2, figure 3).

	Degrees of Freedom	Sum of Squares	Mean Squares	F Ratio	P Value
Local	1	1.589	1.5889	4.0002	0.04584 *
Residuals	773	307.038	0.3972		

Table 2: Model outputs of analyses on ordinal data for Aldabra Atoll.

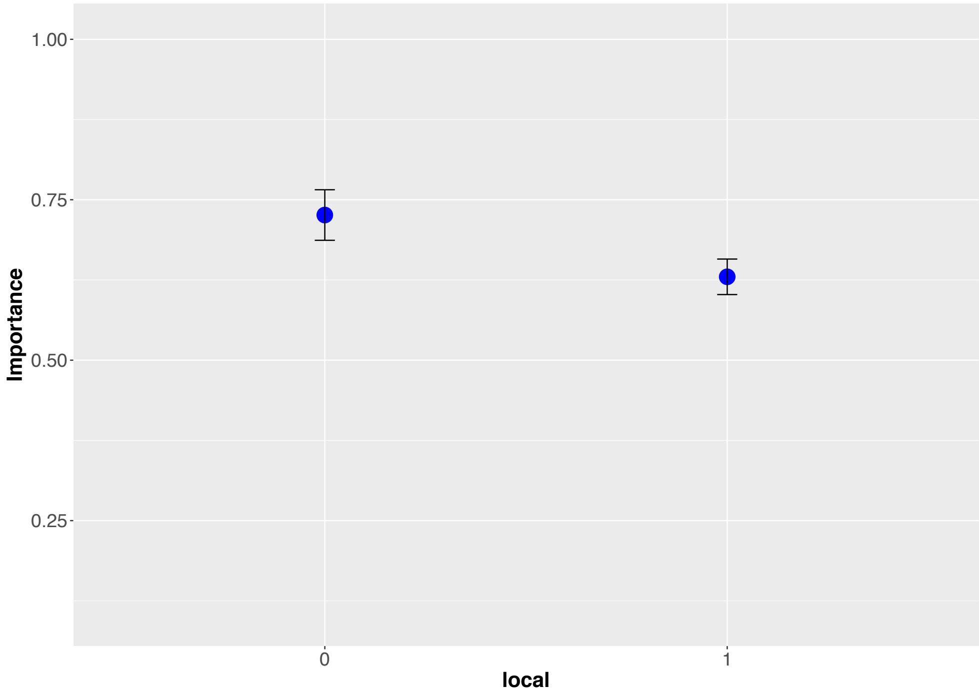

Figure 3: Variability in level of importance assigned to ecosystem services on Aldabra Atoll. Interviewees who are local give higher importance scores than those who are not.

3.1.2 Haibei

As with the Aldabra data, I ran a number of more complex models that tested additive and interaction effects of the variables for individual attributes at Haibei. In this case, the model that explained the most variation took occupation (*occn*), connection to the site (*conx*) and gender (*gen*). Slightly higher scores in general from academics and site officers can be inferred, while local people and men are slightly more likely to give lower importance scores (table 3, figure 4).

	Degrees of Freedom	Sum of Squares	Mean Squares	F Ratio	P Value
occn	3	2.03	0.67710	2.8960	0.034074 *
conx	2	1.72	0.85771	3.6684	0.025740 *
gen	1	2.09	2.09221	8.9484	0.002821 **
Residuals	1539	359.83	0.23381		

Table 3: Model outputs of analyses on ordinal data for Haibei.

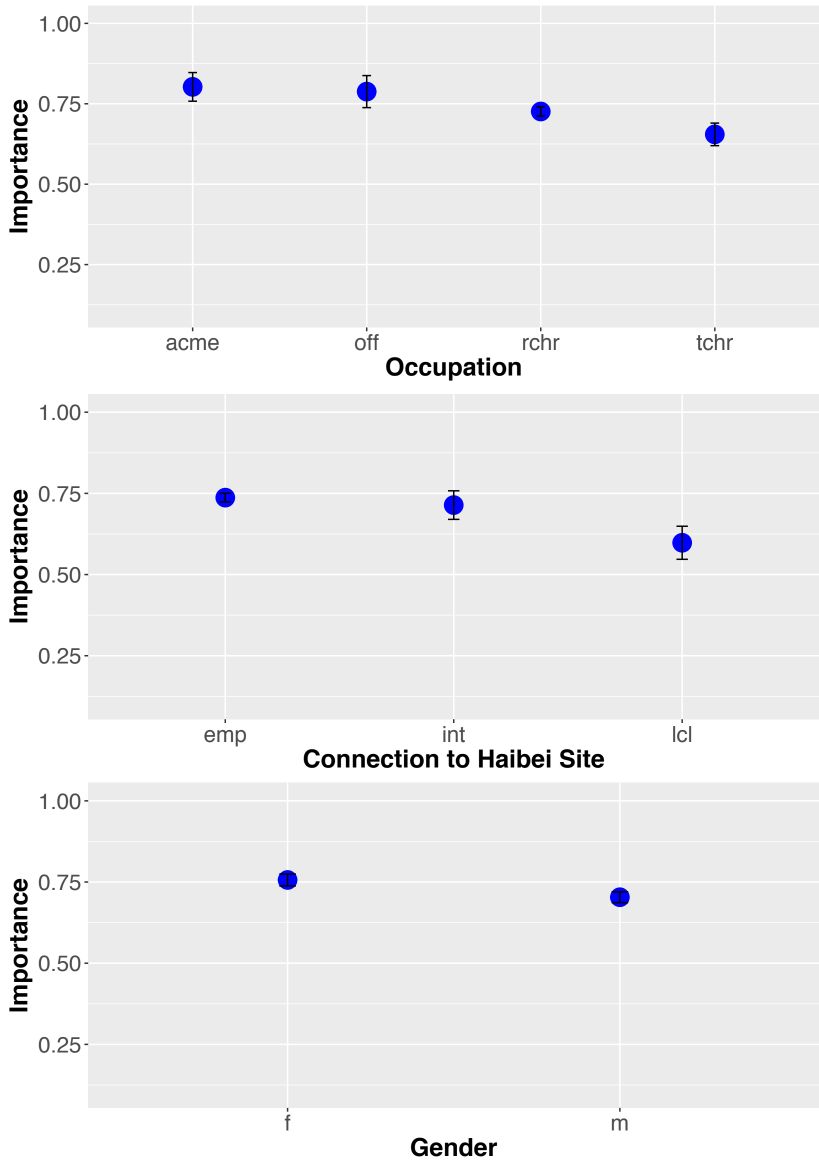

Figure 4: Variability in level of importance assigned to ecosystem services at Haibei Alpine Meadow Research Station. Interviewees who are teachers, those who are local, and men give slightly lower importance scores. Original data ranges from 0-3. This was transformed to the inverse sine of the square root, restricting the range to 0-1, as shown on the y axis.

3.1.3 Individual services

The models for Aldabra and Haibei used repeated measures in the explanatory variables. That is, each individual is repeated for each ecosystem service. Lack of sufficient data points meant that I could not reduce the analysis to one service at one site. I tried an alternative analysis that pooled the data from all sites for each ecosystem service and found that in all but seven cases, *site* is the most important or equally important explanatory variable.

With *site* removed, a limited number of services show a small effect of individual attributes. Interviewee age and occupation appear to most frequently affect response patterns (eleven services each), along with education level (seven services). There is one instance of a slight effect of years of experience (09, spiritual).

In order to see if these effects were better explained through reordering the services, I ran principle components analysis (PCA) on the full dataset. I hoped to reduce the dimensionality (number of services) of the data. This in theory gives an indication of series that grouped similarly according to their importance scores. However, this data reduces to eight dimensions that roughly correspond to site. In effect, while there is variability in the ordinal data, it is not possible to explore it beyond site or ecosystem service level. The low sample size at site level makes exploration of each service at each site unreliable.

3.2 Uncertainty Data

I shifted my approach to look at certainty in the binary data, and to make clearer distinctions between the responses for each ecosystem service. I restricted my analyses to the most uncertain services at two sites, Aldabra and Haibei.

3.2.1 Aldabra

There are three ecosystem services at Aldabra that meet the 10% criteria, eliciting 51 responses, and with all eight explanatory variables included in the models. These are 25 (plant-based resources); 26 (animal-based resources); and 46 (chemical condition of salt waters). Based on the binary responses, I plotted predicted values (likelihood of being certain) with standard error (se), estimated from a binomial generalised linear model for each explanatory variable (figure 5). The outputs give attributes that may make interviewees more likely to give certain answers. Error bars are large, as expected with a small sample that is unlikely to be a representative selection of individuals. In some cases (education level - college; occupation - management and teacher), the error bars are on the mean, suggesting all individuals representing that category gave the same response.

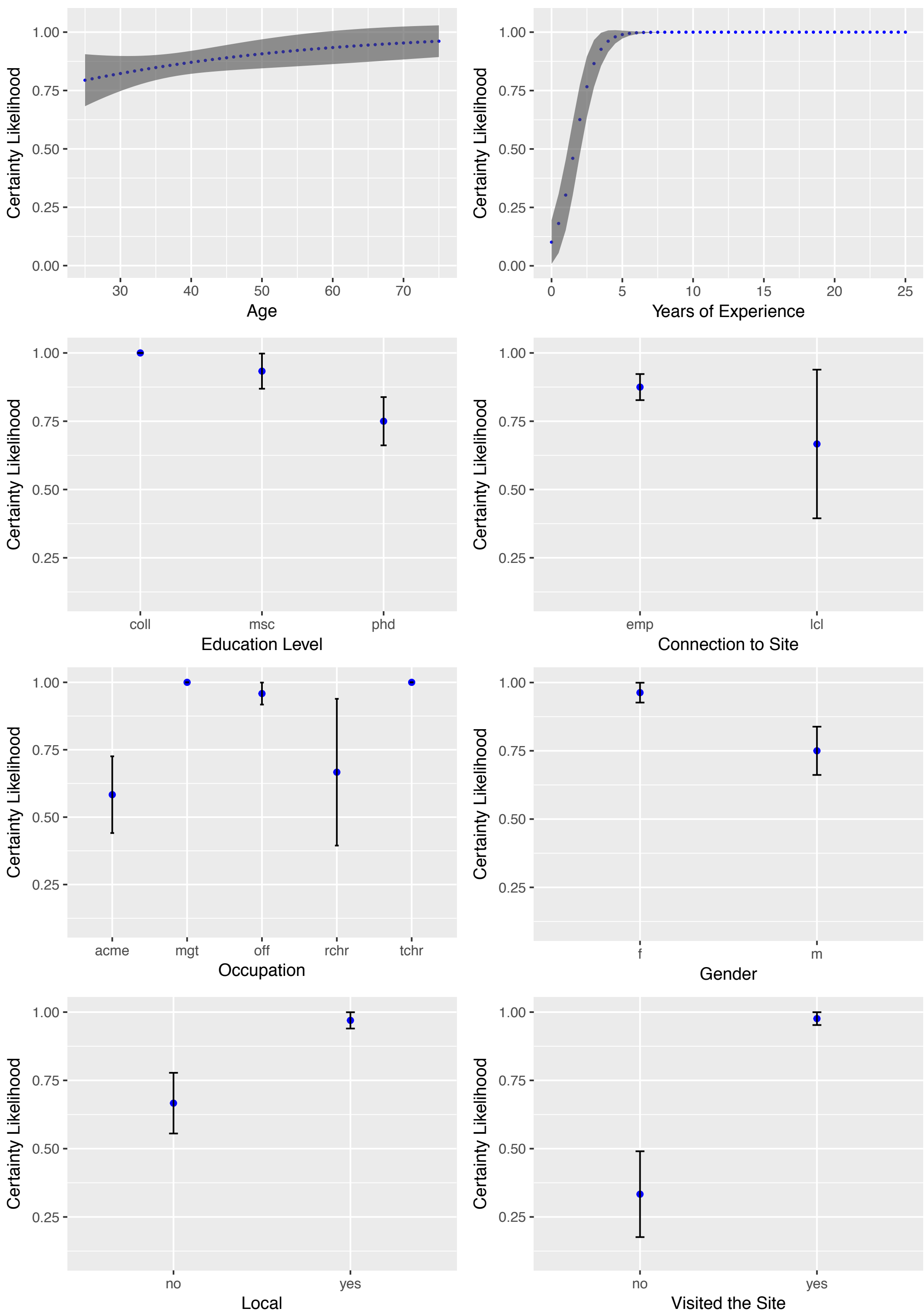

Figure 5: predicted values and standard error (se) of how likely individuals are to respond certainly (*yes* or *no*) about the presence of ecosystem services on Aldabra Atoll. Values near to 1 indicate higher likelihood of certain responses. N *esv* = 3, n observations = 51

I used analysis of variance (ANOVA), with Chi-squared to test the overall effect of the different attributes on the responses given. This analysis gave deviance tables from which I calculated approximated r^2 (% deviance change) and quasi F statistics to account for the underdispersion in the data.

variable	p	corrected p	% deviance change (r^2)	quasi F	dispersion
yexp	9.35E-07***	4.835E-11	58.97%	0.34	under
vis	8.22E-06***	1.23E-08***	48.75%	0.43	under
local	0.00282***	0.000542***	21.86%	0.65	under
occn	0.01486*	0.00198**	30.3%	0.62	under
gen	0.02197*	0.00974**	12.87%	0.73	under
ed	0.03966*	0.01601*	15.82%	0.72	under

Table 4: Recalculated analysis of deviance outputs for Aldabra Atoll.

The results for Aldabra all show strong underdispersion of the data - less variability than predicted by the model. Consequently, although the significance values for the effect of gender and education level on responses are lower than for the other attributes, there is less underdispersion in this data, so the values for these two variables are more robust.

I explored more complex iterations of the full linear model to test the additive and interaction effects of the explanatory variables.

variable	p	corrected p	% deviance change (r^2)
yexp	9.4E-07***	8.9E-12***	59%
vis	0.2267	0.02968*	3.6%
local	0.1352	0.00803**	5.5%
yexp:vis	0		
yexp:local	1		
vis:local	0		
yexp:vis:local	0.9999	0.5	32%
Residual Mean Deviance: 0.29 under dispersed			

Table 5: Outputs of interaction model for Aldabra Atoll. 0 and 1 for the interaction terms are due to a large amount of missing data.

For Aldabra, localness, years experience, occupation, education level, gender and whether interviewees had visited the site all show effects when placed first and last in the model. Reducing the number of variables in the model to those with the lowest p values leave years experience, whether someone has visited and localness as the most important explanatory variables. I reran the model with these variables additively (main effects) and as interaction terms (dependent variables). Recalculating the outputs to account for underdispersion in the data gave the outputs in table 5 above.

These results suggest that there is no interaction of the three explanatory variables, and each accounts separately for variation in the data, implying that if an individual has more experience with the research site, if they have been there, or if they are local, then they are more likely to be certain in their responses.

3.2.2 Haibei

For the Haibei site there are thirteen ecosystem services with at least 10% *I don't know* responses. Of these, three are cultural, six are provisioning, and four regulating. None of these are the same as for the Aldabra site. This gives a total of 498 responses, with seven explanatory variables. All interviewees in this dataset had visited the research area, so this variable was removed.

As before, I plotted the predicted values with standard error (se), for the data from Haibei using the same GLM as for Aldabra (figure 6).

Proportionally, most responses are certain, as figure 6 shows, although for all variable categories there are slight differences in certainty. Broadly, the plots suggest that older people, people who have more experience at the research site, people with a lower level of formal education, local people, and site managers and officers, are slightly more certain in their responses.

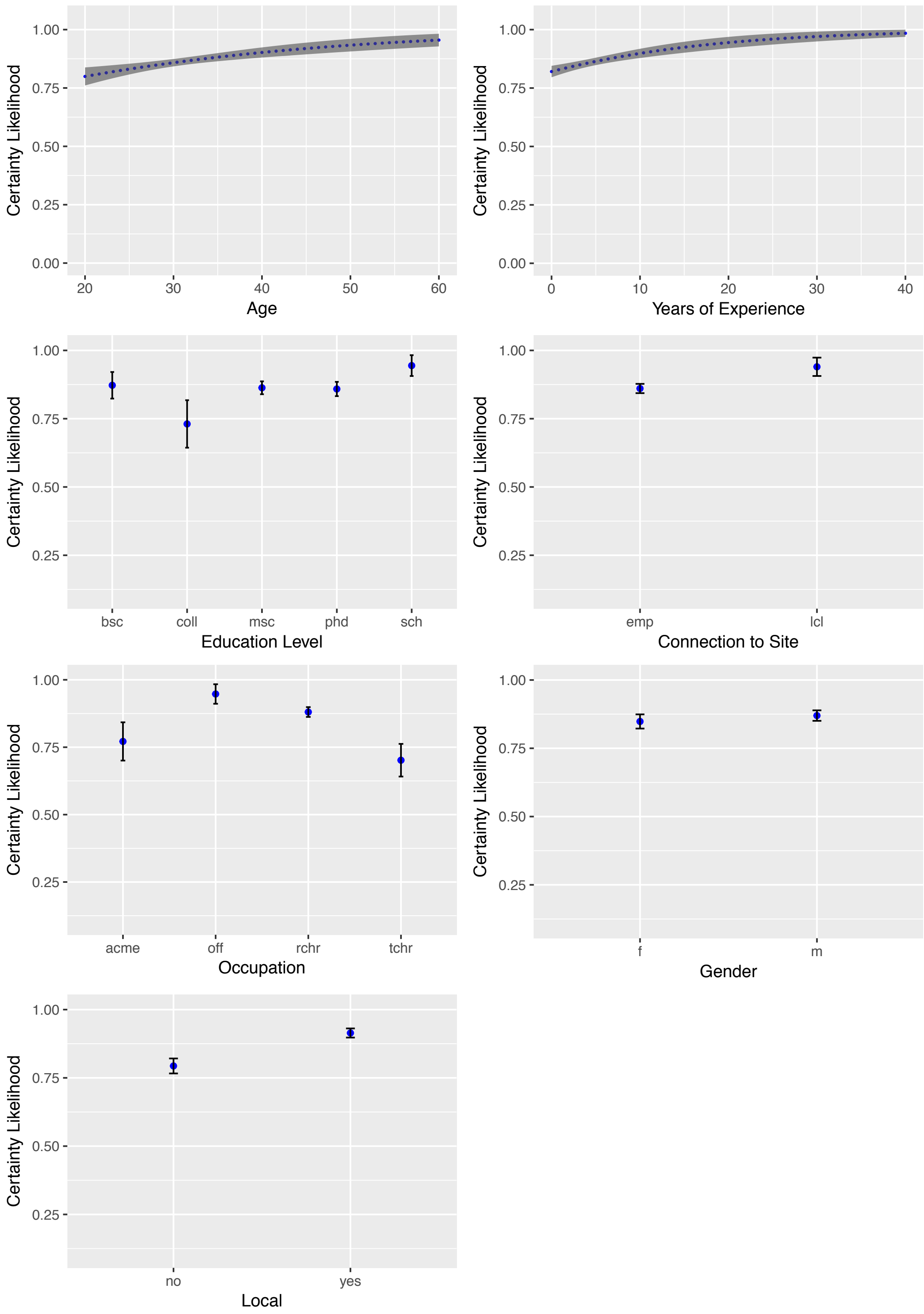

Figure 6: predicted values and standard error (se) for the likelihood of individuals responding certainly (*yes* or *no*) to questions about the presence of ecosystem services at the Haibei research site. Values nearer to 1 indicate higher likelihood of certain responses rather than *I don't know* responses. N services = 13, n observations = 498 (42 individuals), NA = 48.

To test these differences, I then ran ANOVA and chi-squared tests for each GLM, and I calculated quasi F statistics to get the following outputs:
anova(m1, test="Chisq")

variable	p	corrected p	% deviance change (r^2)	quasi F	dispersion
local	0.000346***	0.000076***	3.45%	0.8	under
occn	0.001411**	0.000271***	4.19%	0.8	under
yexp	0.003364**	0.001043**	2.15%	0.79	under
age	0.02785*	0.0141349*	1.21%	0.8	under
conx	0.05931.	0.0329006*	1.52%	0.82	under

Table 6: Recalculated analysis of deviance outputs for Haibei.

In all cases, the deviance explained is very low, although this is not unexpected with data for people, and again the data is under-dispersed, These outputs for each variable tested separately suggest that the plotted differences between people are significant for connection to site, occupation and whether or not someone is local.

I then ran multiple iterations of the full model to find explanatory variables that explained more of the variance when ordered first and last. For Haibei, years experience, occupation and whether an interviewee was local or not all show significant effects in these models. I recalculated the GLM and ANOVA with these three variables additively (main effects) and as interaction terms (dependent variables) (table 7).

variable	p	corrected p	% deviance change (r^2)
local	0.00035***	2.6E-05***	3.45
yexp	0.00597**	0.00119**	2.04
occn	0.00432**	0.00041***	3.54
local:yexp	0.06397.	0.028479*	0.92
local:occn	0.28077	0.1683993	0.68
yexp:occn	0.1046835	0.035322*	1.66
local:yexp:occn	4.8E-05***	1.9E-06***	4.46
Residual Mean Deviance: 0.71 underdispersed			

Table 7: Outputs of interaction model for Haibei.

When the interaction terms are included, the three main effects (years experience, occupation and being local) remain largely the same, with little effect of two-way interactions. The interaction of all three terms is highly significant but again the data is underdispersed and 83.24% of the residual data unexplained. Fisher scoring for this model is 16, with AIC=334.85.

These results suggest that interviewees who are local, or who have more experience at the research site, or who are employed as site officers are more likely to be certain in their responses. Any individual who combines all of these variables is also more likely to be certain.

3.3 Disagreement Data

There are 34 services across the full dataset that have high disagreement, three (proportionally 14.15%) cultural, twelve (38.91%) provisioning, and nineteen (46.94%) regulating. As with the uncertainty data, there is more disagreement in the responses to questions about the presence of regulating services, and less with cultural services. The full list of services and sites where there was disagreement is given in Appendix 4.

I ran classification trees with the full dataset before filtering for those services with higher levels of disagreement. As with all other analyses, *site* and *esv* predominantly determine the responses given, although age is also used to partition the data. There is a clear division of the services where people said *yes* in at least 75% of responses, while services 16, 17 (both animal and plant-based aquaculture), and 27 (animal-based energy) had *no* in at least 75% of cases. *Site* is then important for determining the clearly present and clearly absent services, with Aldabra and Kytalyk having 66.94% *no* responses for a further 12 services. For other sites, whether someone was younger or older than 30 partitions the *yes* and *no* responses, which are then further partitioned by *site*. For example, people older than 30 gave 84.21% *yes* responses for 26, and 66.67% *no* responses for services 19 (ground water for drinking), 24 (ground water for non-drinking purposes), 32 (mediation of smell, noise and visual impacts), 37 (storm protection) and 46.

While this helps to see how the data partitions, there are a number of issues. Firstly, a large number of splits reduces the amount of data and leads to over-fitting of the tree and branches. Secondly, using the full dataset is helpful to visualise which services have clear responses and which are more mixed but it does little to help partition below the level of site and service. Lastly, each service elicits different responses, giving indications of which people made which decisions for each service but creating a far more complicated overall picture if we want to be able to generalise about whether certain groups of people are more or less likely to give the same responses. To do this, we would ideally have a classification tree with few branches leading to nodes that show clear divisions of responses by person attribute.

I reduced the full dataset to only services with high disagreement (between 0.33 and 0.66 *yes* and *no* responses), as little or no disagreement suggests all interviewees respond *yes* or *no* and there is no variability to analyse, and ran the same analysis. In this case, while *esv* and *site* are still used, they are less important than in the previous model and a number of attributes partition the responses.

The services with a proportionally higher number of *yes* responses do not partition further (5, 8, 13, 15, 21, 30, 31, 34, 36, 37, 40, 43, 47 have more *yes* than *no* responses, 59.8% of all responses for these services are *yes*). This does not mean that there is no disagreement about the presence of these services, clearly there is, as still less than two thirds of interviewees said *yes*. However, the explanatory variables given do not meaningfully partition the data any further.

The proportionally higher *no* responses are more complicated and partitions include: how long someone has worked at a site (yexp >=4.8 or <4.8); occupation (*mgt*, *other*, *rchr*, *tchr* or *acme*, *off*); age (<35 or >=35); gender; and education level (*coll* or *msc*, *phd*). These attributes to some extent determine who will respond *yes* or *no* for some but not all ecosystem services. However, the probabilities are low, and so have little predictive power. For example, women who are younger than 35 with less than 4.8 years of experience on Aldabra more often say *no* than *yes* for the eight ecosystem services that have a proportionally lower number of *no* than *yes* responses. However, the absolute numbers that determine this are *no*=6 and *yes*=1, and represent the responses of one individual. Error with all variables = 0.7579.

With *site* and *esv* removed, the relative error is higher (0.8235). A less complex model is generated, and *yexp*, *ed*, *gen*, *age* and *vis* are used to partition the data. For example, people who have 4.8 or more years of experience at a site and are educated to bachelor level give more *no* than *yes* responses, while women who have visited a research site and who have less than 4.8 years of experience give more *yes* responses (112:55). Those who have not visited give more no responses (3:8). Age is the most important variable (29%) and determines the divisions within the *no* responses, although the differences between the groups are not large.

I again used only the data from Aldabra and Haibei but for Aldabra the insufficient data meant that I couldn't generate classification trees. For Haibei I partitioned by ecosystem service and each attribute separately, and combined all explanatory variables.

3.3.1 Haibei

The full classification tree for Haibei (figure 7) initially partitions by gender, with women more often responding *yes* than *no* overall. The only service where men and women both give more *yes* than *no* responses is 05 (heritage, cultural benefits). There is greater agreement for services with more *no* responses, although for women and men in particular, these responses are further partitioned by age, connection to the site, and years experience.

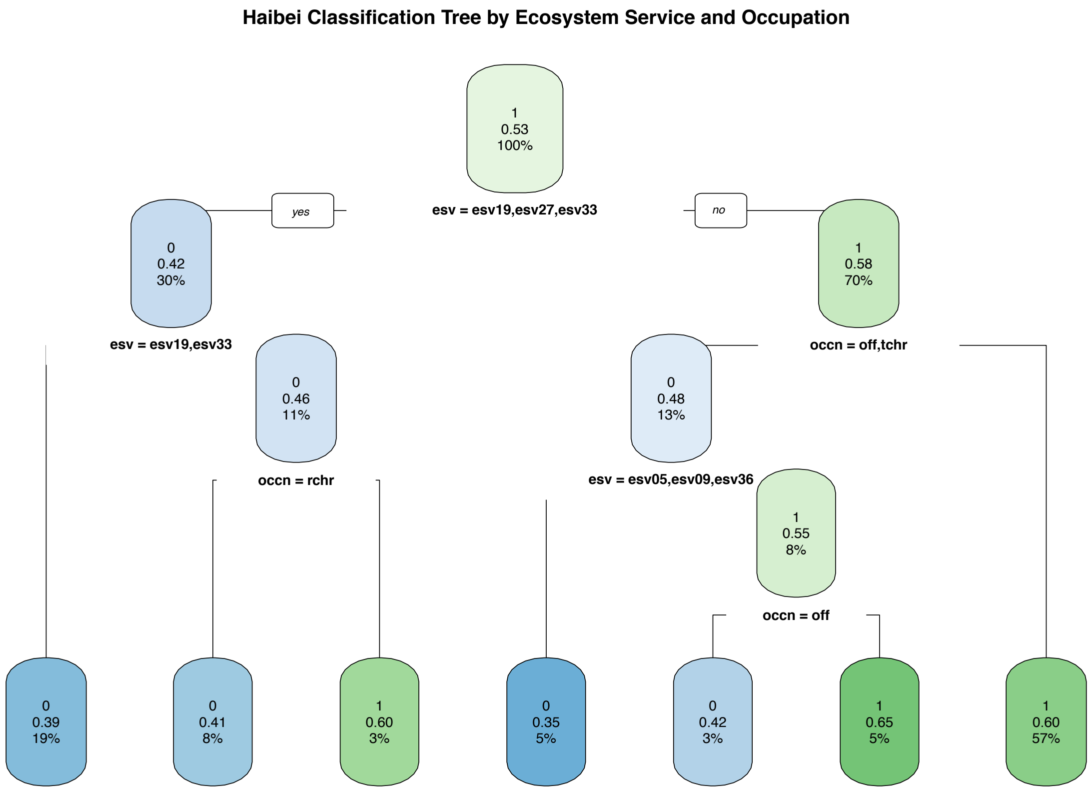

Figure 7: Haibei classification tree, using ecosystem service (*esv*) and occupation (*occn*). Green boxes = higher proportion of *yes* responses, blue = *no*. Numbers in each node indicate: response type (*yes* = 1, *no* = 0); probability of responding *yes*; and % of all data used in each node. Root node shows the overall probability of responding *yes* = 0.53. Services 19, 27 and 33 are lower (0.42), responses for 27 partition by occupation type. Probabilities in the terminal nodes are calculated from very low percentages of the Haibei dataset.

Looking at each variable separately, there are multiple divisions by different *age* classes for responses to each service, leading to more final nodes than services, making generalisations about groups that disagree untenable. In general, people who are connected to the site through interest, rather than through being a local resident or employed to work there, more often respond *no* to services that have a higher proportion of *yes* responses. Neither education level nor whether someone is local or not, produce branching trees. When only ecosystem service and gender are the explanatory variables, the general pattern is that women give more *yes* responses to services with proportionally more *yes* in total. Men give more *no* responses overall, except for services 05 and 36 (flood protection). Interviewee occupation partitions by site officers and teachers on the one hand, and academics and researchers on the other (figure 5). For services with proportionally more *yes* responses, academics and researchers say *yes* more often than *no*, while site officers and teachers say *no* more for services 5, 9 (sacred/religious benefits) and 36. Site officers and teachers also disagree about four services. As with age, the classification tree for the how much experience someone has with the site is also complex. Broadly, people with 0.75-2.5 years more often respond *yes* for all services that have more *yes* than *no* responses, while those with more than 4.5 years experience more often respond *no* to services with a higher number of *no* responses. Within these broad patterns, there are a number of different divisions by age and ecosystem service.

Overall, classification gives a complex picture of how interviewees respond differently to services where there is disagreement, without consistent, strong patterns according to individual attributes. The ecosystem service in part determines how the groups of people who agree and disagree are configured. This is even more complex for the full dataset, and while it may give some indication of where groups disagree, it is not possible to draw more general conclusions about this.

4 Discussion

4.1 Differences in Importance Scores

Both Aldabra and Haibei showed some effect of being local – that is that local people tend to give lower importance for ecosystem services than those who are not. Perhaps being local leads people to be less aware of the importance of places that are more familiar and less 'new' in an their perceptions. At Haibei, other attributes were also relevant, including gender. When discussing importance, men give lower scores than women. However, these small differences should be treated cautiously, not least because site context and ecosystem service continued to be better indicators of importance scores. A greater range in the importance data along with more interviews and a more even distribution of attributes would help in better understanding whether there are patterns of perceptions at each site, as well as across them.

4.2 Uncertain Services

Across the full data set, regulating services more often showed uncertainty than either cultural or provisioning service (50% of all uncertain services, proportionally 39.3%). However, the most tangible services – provisioning – made up almost half of all the services that I used for the uncertainty analyses for Aldabra and Haibei (49.46%). Across the full dataset they represent just under one third of all uncertain services, so it is necessary to consider why interviewees from both Aldabra and Haibei are more uncertain about these services.

On Aldabra, the legality of the use of plant and animal resources (25 & 26) might in itself be perceived uncertainly. Interviewees know that no harvesting of any materials is allowed, on the other hand, small amounts of driftwood are occasionally used for barbecues, although island residents are not dependent on this for fuel. Possibly, even when these are used for fuel, the quantities are so low that the use and subsequent benefits could be perceived as negligible by interviewees. Animal resources are not taken away from the atoll, but a small amount of tortoise dung is used as compost in the kitchen garden, although again, how much this happens or how necessary it is may conceivably be perceived uncertainly. A few individuals also mentioned the use of driftwood and other objects to make decorations. As with fuel, these are small quantities and it might be difficult for interviewees to connect these to any real, visible extractive use of resources. I suspect this could also be linked to the previous history of the atoll, where extensive planting, harvesting and extraction of resources were its main use, and were ecologically devastating. Although these activities do not now take place in any tangible sense, interviewees still have knowledge of the island's past, indeed for the Seychelles as a whole. Ecosystem service 46 (chemical condition of salt waters) may well be viewed uncertainly due to differences in scale. While the atoll is fully part of the marine system, to claim that it is able to exert any regulation of the quality of the water may seem rather overstated. Interviewees may well be giving unclear responses because although they understand the concept they don't feel able to definitively state that regulation takes place. Equally, possibly they are reluctant to deny that Aldabra performs any role in this.

The situation in Haibei is somewhat different, in fact in terms of spatial scale it is at the other end of the spectrum. The research site is located within the vast region of the Tibetan plateau, where the boundaries of the specific research site, the administrative districts and the autonomous regions are widespread and potentially fuzzy. Consequently, it may be difficult for interviewees to be sure about the specific location and then use of some resources, and here there may be some similarity with service 46 on Aldabra. The hydrology of the Qinghai-Tibetan Plateau is complex, with diffuse water sources coming from high mountain areas into widespread river systems and wetlands that are relatively flat and slow flowing. It might be unclear whether drinking water (18 and 19), which has to be treated, is coming from ground or surface water sources, and interviewees may not know the links in the processing chain that make drinking water available in downstream towns and cities. For similar reasons, whether the area protects from or is a source for flooding (36) is also unclear. The use of wild animals (14) also seemed to be connected to the genetic use of biota (22), creating some possible conflicting in understanding. Several interviewees talked about collection of wild animals for research rather than for subsistence, suggesting that there is uncertainty about what wild animals are being used for.

4.3 Uncertain People

As with the importance data, there is a general suggestion in the analyses that people who exhibit more certainty are local and have more experience of the area. In some cases, it seems that there is higher certainty from people who are employed in connection to the site. Education level and academic position appear to have no influence on certainty.

The data from Aldabra is not really sufficient to draw firm conclusions about individual attributes that might explain why interviewees give uncertain answers about some ecosystem services. On the other hand, the attributes that show some effect here can be rather easily explained, if we tentatively accept that someone who has less experience with the research site, or has not visited it, or is not local, is more likely to give uncertain responses. The interviews for Aldabra were all conducted face-to-face, and there were many people who had spent a considerable amount of time on the atoll and who had a great deal of in-depth knowledge about it. It is uninhabited and remote, which could make it difficult for people who are less familiar with Aldabra to imagine the roles it plays in the lives of people who live both near to and very far from it. However, those interviewees who have spent time there clearly expressed the high importance of some services to a very small number of people, such as driftwood for lighting occasional barbecues and tortoise dung as compost for the kitchen garden. The impacts and uses are extremely localised and quite possibly hard to imagine or consider without experiencing life on the atoll itself. Although I found no interactions between attributes, working on the atoll does in general require people who have a commitment to going there for at least 6 months and then of spending time on research and later work.

The analysis from Haibei is somewhat more robust and I also detect an interaction between all three attributes that show some effect on uncertainty. Being local, working at the site for longer and being a site officer or researcher made people more certain in their responses. There is also a clear interaction between all three of these variables, which is unsurprising, at least for interviewees who were site officers, since they had generally been working at the Haibei site for several years. Longer experience should facilitate a greater knowledge of the area. What is interesting is that academics were not more likely to be certain and neither were those with higher education levels. There was also no effect of age, although clearly more experience might suggest that people are also older. In short, experience, direct knowledge of the system and how it fits into the wider local context allow people to be more certain about the presence or absence of ecosystem services.

4.4 Services that lead to disagreement

As with uncertainty, disagreement across the full dataset appears to be higher for regulating services (19 of the 21 services were included). Both services from Aldabra, and half of the ten services from Haibei were regulating services. Regulating services might be eliciting more disagreement due to the scales at which they are understood to be functioning. They may also be badly described and then not well understood by interviewees.

The highest disagreement for Aldabra was for the hydrological cycle (35) and pest control (41). I think here there are two different issues. Many people talked about Aldabra, as an isolated land mass in the Indian Ocean creating its own weather system, however, it is in itself relatively small, and additionally very dry during the dry season. Although it has its own hydrology, it is freshwater limited. Consequently, while some people were able to perceive this as still a service, others may have felt it was not significant for people, similarly to the use of resources discussed above. Pest control on Aldabra often elicited responses related to invasive species, and so I think here there is some effect of a negative phenomenon included within the terminology around this service, as well an issue of temporal scale. Invasive species have historically been a problem on Aldabra and continue to be on nearby Assumption. Interviewees are generally very aware of the impacts of invasives. However, there has also been a concerted effort to eradicate invasive species, to the point where they are far less of a problem now, however some interviewees may still consider pest control to be an issue on Aldabra and find this service as a way to express this.

For Haibei, as for uncertainty, the size of the area may make it hard for interviewees to perceive the effects of some ecosystem functions. While people talked about erosion, some would talk about it being a problem, while others didn't perceive it within such a flat landscape. I think this might be similar for flood control, although this might also be related to knowledge about whether any downstream communities were affected by flooding or not (Apostolopoulou et al., 2012b). Ventilation and transpiration was also talked about in different ways. While some people emphasised how clear the air was, and that such a huge area must be having an effect, others may have perceived either a lack of taller vegetation or distance from centres of habitation as barriers to this being a benefit provided by the site.

4.5 People who disagree

As the classification trees couldn't be applied to the Aldabra data, it isn't possible to draw conclusions about attributes that may explain the disagreement.
For the data from Haibei, seven attributes showed some importance in partitioning the data (ecosystem service, age, years experience, gender, education level, connection to the site, occupation). The effect of gender shows here as for the importance data, with a tendency for women to say *yes* (62.77%) rather than *no* slightly more often than men (47.22%). However, the patterns of who says *yes* and *no* depend on the service and partition by connection to the site, years experience working at the site and age. The difficulty in finding single attributes that explain which groups of people disagree may be due to the difference in each service.

If I look at the disagreement patterns at Haibei in relation to importance and uncertainty, there are some trends that I would tentatively suggest.
Gender plays a role at this site, and it appears that men give lower importance, are more certain in their responses and very broadly say that a service is not present when women say that it is. However, this broad pattern breaks down in the disagreement data once ecosystem service is taken into account. Here age and occupation may be better indicators of how men respond, with those in their 40s also more frequently saying *no*. People who are local give lower importance and are more certain in their responses, while for some services they more often say *no* than others. Having longer site experience may allow people to be more certain in their responses and, broadly, to say *no* more often than *yes* for some services.

4.6 A note on Cultural Services

Cultural services are present, important and elicit less uncertainty and disagreement than either provisioning or regulating services. This is vitally important to acknowledge, since they are at the same time frequently posited as the most difficult services to map and quantify. In order to include perceptions, possibly cultural services, with their multiple meanings and values, are a good entry point with less potential for conflict between actors and more points in common.

4.7 The importance of Site

There is an effect across these analyses of ecosystem service section, with a general trend for regulating services to be perceived more uncertainly and for people to disagree about them more often. However, there is clearly a greater overarching effect of site on all of the data. Between the two sites selected, there was little overlap of services for uncertainty and disagreement, and for these two sites, provisioning services elicited greater uncertainty from interviewees. This reinforces other work that shows a very strong effect of site on the suite of ecosystem services perceived to be present and important by interviewees. This is fundamentally important for understanding that ecosystem services are a reflection of the context within which they are generated and benefitted from. It is likely that, despite all our best efforts to map them, they will remain unique to site and to the range of beneficiaries once we move away from purely empirical methods towards more conceptual approaches (de Groot et al., 2002; Costanza, 2008; Fisher et al., 2009; Dobbs et al., 2011). This means that understanding the perceptions of ecosystem services, natural capital or nature’s contributions to people of multiple actors is extremely important for fully integrating multiple needs, uses and values into policy and management work. Ideally, there would be a large number of interviews at any one site with variability in some responses about the presence of each service. Additionally, the people interviewed should sufficiently differ in a selection of characteristics, for example education level, age and occupation.

4.8 The importance of localness

It is also critical to note the strong need to integrate research agendas and outcomes with management at every site (Saarikoski et al., 2018). Even though the interviewees here were actors in the sites and this study was not focused on the broader local community that a diversity of views still comes out in all three analyses is very important. Many of the interviewees at both sites could still be considered local, if not indigenous, knowledge holders, who are increasingly acknowledged as integral to addressing barriers and implementing change (Díaz et al., 2018; Saarikoski et al., 2018), as well as being able to provide informed, rich information on systems. If I was able to find disagreement within my selected sample of interviewees, a broader selection of people would yield much richer picture of how dependencies on nature are perceived and of what might influence how individuals see these dependencies. I don't think I necessarily found conflicting views from researchers and managers but it is clear that without local actors, whether they are site managers, doctoral students or professors, is extremely important for beginning to align research and management objectives. Even if a postdoctoral researcher who is local, for example, is not directly involved in site management, their understanding of site context, and of wider local concerns will allow them to have much clearer perceptions about the site. Bearing in mind the current push to include multiple types of knowledge in ecosystem service assessments, it is encouraging to observe that local people are adding information. Clearly, even for those who are carrying out empirical work within the system, having the additional attribute of being local confers different perspectives about ecosystem services.

4.9 Beyond Empirical Approaches

I detect differences in attributes that contribute to disagreement and uncertainty at the sites I looked at, but also that each site influences the suite of services and how they are perceived. This is essential to understand, if we accept that ecosystem service assessments are operating in co-created, social-ecological systems. The ecological system is shaped by the society that exists within and depends upon it, but equally society is shaped by the ecosystem, influencing our perceptions and values. To ignore this in favour of biophysical or economic quantification of the ecosystem, or in favour of assessment of the social system creates research blind spots. Such blind spots lead to misrepresentation, misunderstanding and conflict, particularly if people feel that their own perspectives and values are ignored. Efforts to be more inclusive, open and informed about people and the ecosystem that they depend may have promise over a more economic approach, and lead to more widely accepted decision making. If we are to continue for push for policy traction in ecosystem services work, we need to be sensitive to peoples' perceptions and values.

Chapter 3

The Value of Nature is More than the Sum of its Ecosystem Services

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Contribution: 70-90% (conception, fieldwork, analysis and writing)

Abstract

In this work, I explored whether the experts that I interviewed for their perceptions about baseline ecosystem services at multiple research locations also revealed their own values for those locations. Previous analyses were on quite constrained yes/no and importance ranking responses. However, as the interviews were semi-structured, they allowed interviewees to expand on these more simple answers, voluntarily disclosing their impressions, thoughts and emotions connected to the places they were speaking about. This facilitated a more inclusive process that allowed me to explore and better understand the answers, specifically through the perspective of different types of values.

I used qualitative content analysis (QCA) (Mayring, 2015) to evaluate the interview texts for the types of values individuals expressed about place, within the context of ecosystem services. I looked for the articulation of instrumental, intrinsic and relational values, all categories of value proposed and critiqued in the existing ecosystem services literature (McCauley, 2006; Chan et al., 2012b; Jax et al., 2013; Chan et al., 2016, 2017). In the context of ecosystem services, interviewees revealed instrumental value types most frequently, and expressed the highest number and widest range of values when describing cultural services. Broadly, I found that instrumental values are aligned with provisioning ecosystem services, intrinsic values with regulating services, and relational values with cultural. However, interviewees gave multiple types of value for most ecosystem services, often combining instrumental and relational value types for single ecosystem services. I also found that the values interviewees expressed for any given ecosystem service depended on the site being discussed.

This work illustrates that recognising the diverse, layered values that individuals construct around the multiple contributions that ecosystems make to their lives is essential for the integrity of engaged, co-produced, and relevant environmental science, research, and policy making.

1 Introduction

1.1 Background

There is continued debate about the role of valuation and values in the field of ecosystem services. This is currently most evident in the division over terminology, shifting from the more ecological/economic connotations of nature serving people implied by *Ecosystem Services*, towards the more nature-focussed and human dependency terminology in *Nature's Contributions to People* (Díaz et al., 2018; Braat, 2018; Masood, 2018). The following study explores in more general terms the types of values, already outlined throughout the ecosystem services literature (de Groot et al., 2002; Yung et al., 2003; Butler and Oluoch-Kosura, 2006; Baumgärtner, 2008; O'Neill, 2008; Agbenyega et al., 2009; O'Brien, 2009; Ghazoul, 2010; Chan et al., 2012b; Jax et al., 2013; Cole et al., 2015; Connell et al., 2015; Gould et al., 2015; Amberson et al., 2016; Chan et al., 2016; Gunton et al., 2017), that individuals mention when describing discrete locations through the ecosystem services paradigm.

1.3 Ecosystem Services

Ecosystem services have grown out of ecology and conservation as scientists have struggled with the need to clarify how intimately human society is dependent on the earth in order to foster better care of it (Chaudhary et al., 2015). It is a field borne of frustration at the inability of ecological science to more strongly influence society to live sustainably (Geijzendorffer et al., 2017; Saarikoski et al., 2018), despite an increasingly detailed understanding of the interconnectedness of humans and nature (Folke et al., 2016), and the knowledge that our own well-being is tied to the well-being of the places where we live (Haines-Young and Potschin, 2010). The birthing of ecosystem services from this ecological and economic background has given the field a specific approach and terminology that is still renegotiating itself. While the research and debate continues around more inclusive language, wider and more informed data collection, and improved methods and models, there are some facets of the paradigm that remain to define it.

Although their exact definitions and indicators are mutable, we continue to have the broad ecosystem service sections cultural, provisioning and regulating (regulation in CICES V5 (Haines-Young and Potschin, 2017). Provisioning services are largely extractive – people harvest timber, hunt pigs, eat fish – with named species and specific uses (Huntington, 2013). In general these are benefits that meet basic needs and involve material goods that can be quantified and given a market or exchange value. As ecosystem services, they are perhaps the easiest to measure and assign value to, as society already places tangible values on these goods and benefits. It is important to acknowledge that the market values that society gives to these services do not necessarily reflect the true environmental impact of the extraction and use of these resources. Damming a river for water reservoirs can have construction costs and water prices that account in part for their value. However, the loss of land, long term impacts on the wider ecosystem, loss of species and habitats, as well as the social costs of displacing inhabitants are rarely, if ever included in a purely economic accounting system.

Regulating services describe those ecosystem functions that ensure our ability to survive on earth (Kremen, 2005). Regulation of hydrological cycles in any location ensures access to water sources, defines areas safe from flooding and informs how crops can be irrigated in a landscape, for example. In some cases, these services can be quantified, for example by measuring the amount of water held back in flooding events, or water diverted for use in crops.

Cultural services are the ecosystem services section that attempts to describe other ways in which people interact with and depend on ecosystems, and more aligned with eudaimonic well-being (Daniel et al., 2012). They embody our emotional and spiritual needs and are generally more complex to measure. Some, such as physical recreation, can be partly quantified by counting the number of day visits to a location, the total length of all footpaths, or the amount of money spent. However, other needs, such as spiritual inspiration, are much less measurable, and demand better examination of what is valued, and what is meant by *value*. As Chan et al. have suggested:

> *"…cultural ecosystem services are both everywhere and nowhere. Cultural ecosystem services, as nature's contribution to nonmaterial benefits derived through human–ecosystem interactions, are everywhere because they are inextricably intertwined with regulating and provisioning services in relationships of material and extramaterial benefits. Cultural services are thus better understood as the filters of value through which other ecosystem services and nature derive importance. Conversely, they are "nowhere" in that many cultural ecosystem services are missing from assessments and resulting policies."* (Chan et al., 2016)

1.2 Ecosystem Services and Well-being

Human well-being depends on certain of our needs being met, and while human needs are complex, our fundamental needs can be reduced to access to shelter, food and clean water (Maslow, 1943). It is easy then to see that some of our most basic needs can only be met by healthy, functioning ecosystems (Corvalan et al., 2005; World Resources Institute, 2005a; Cardinale et al., 2012; European Union, 2014; Folke et al., 2016). However, human well-being is difficult to reduce to only these basic requirements, and different paths to achieve a sense of well-being, are recognised in medical, philosophical and psychological literature (Diener et al., 1999; Ryan and Deci, 2001; Brown and Ryan, 2003; Pretty et al., 2007; Fredrickson et al., 2013). Hedonic well-being, seeks positive affective experiences, satisfying immediate needs (as with Maslow's basic needs), while eudaimonic well-being is a form of seeking meaning and purpose in people's lives (Deci and Ryan, 2008). These forms of well-being are not mutually exclusive and influence one another but they are conceptually different. Some work has also shown evidence for distinct gene pathways for hedonic and eudaimonic satisfaction(Fredrickson et al., 2013).

Ecosystem services can move us some way along the path to understanding the components of systems, and mechanisms that enhance a sense of well-being, particularly in relation to hedonic well-being (Alcock et al. 2014; Bratman et al. 2015). Understanding the connections between ecosystems and eudaimonic well-being is beginning to be outlined in relation to ecosystem services but these are much less researched and understood, although the body of work is growing.

1.4 Perceptions

Information about people's perceptions of place is necessary for better informed decision making. Individuals and groups can have divergent preferences, that, when not considered in decision-making processes can lead to misunderstanding, erosion of trust, and conflict (Agbenyega et al., 2009; Hofmann et al., 2012; Hauck et al., 2013). Carnol et al. for example, have shown that scientists and practitioners perceptions can differ from published scientific studies, and may in fact be more positive about the ecosystem services provided in the systems studied (Carnol et al., 2014). The value of collecting expert knowledge, and conducting expert interviews are supported by this and by work from Hauck et al. that goes further. They demonstrate that published materials, in the form of maps, are not adequate for representing and synthesising the complexity of information related to place. She suggests that there is authority in something published but this does not fully, or even accurately, reflect what individuals perceive (Hauck et al., 2013). These diversions from fact, or published 'reality', are in part due to the influence of socio-economic context on people's perceptions (Hofmann et al., 2012; Carnol et al., 2014). Once we start to look beyond what is directly measurable, for example by evaluating cultural ecosystem services or aesthetics, perception studies begin to help access what is important for people (Daniel et al., 2012). Such approaches may also help in identifying different patterns of ecosystem services hotspots, as suggested by De Vreese (De Vreese et al., 2016). Further, as Poe et al. have pointed out, people's perceptions shape their relation to pace, informing how their values are expressed and their interconnections are built. This is particularly important for recognising the necessity of gathering indigenous and local knowledges that are frequently embedded in practices (Poe et al., 2014).

1.5 Values

Human dependency, inter-connectedness, and relationships with nature are the source of our values, and those values feedback to inform how we act with regard to nature (Maathai, 2010; Sagoff, 2013). Challenges to our values are threatening and are likely to be met with resistance (Norton and Hannon, 1997). These challenges are often unwitting because multiple values are not acknowledged in policy and decision-making processes (Chan et al., 2012b). It is therefore essential to recognise this interplay between values and dependencies, if we wish to find more sustainable approaches to human life on earth.

A number of value types have been explored and described in the ecosystem services literature as components of human well-being (Agbenyega et al., 2009; Chan et al., 2012b; Jax et al., 2013; Chan et al., 2016; Gunton et al., 2017). This literature has traditionally focused on two kinds of value - instrumental and intrinsic value – which are often placed in opposition to one another (McCauley, 2006). In general, provisioning services align well with instrumental values, and regulating services are more associated with intrinsic values, while cultural services do not fit with either. Consequently, this dichotomy has been challenged, with calls to recognize other ways that people value nature, and that they can hold multiple values for one entity. Jax et al. posit four types of value, retaining *instrumental value* as something that is a valuable as a means to something else; redefining intrinsic values as something having *inherent moral value*; characterizing *fundamental value* as the worth of things that are fundamental to life, such as oxygen to breathe or water to drink; and suggesting a category of *eudaimonistic value*, or having a good life. (Jax et al., 2013). Chan et al. expand on these ideas, retaining notions of instrumental and intrinsic value, as these are well-embedded in the psyche of ecosystem services, but creating a category of *relational values*, which expands on Jax' eudaimonistic value while drawing in some elements from inherent moral value and fundamental value (Chan et al., 2016). Of course, these values can be refashioned and are not fixed or necessarily prescriptive. However, they provide a useful base, grounded in the developing values and ecosystem services debate, from which to begin to explore how individuals are connected with place, within the ecosystem services framing. Below I give a brief outline of what I consider to be the three main value categories developed in the literature.

Instrumental values are best understood as valuing how useful something is, and that thing may be replaceable by an analogue. For example, we may consider the value of a tree to be in the timber used for construction, however, the value is in the use, meaning one tree could be replaced by another, or timber could be replaced by concrete. It is the utility that is important, not the entity itself. When we apply a monetary value to entities that are useful to us, for example the cost of a length of sawn timber, we see that we are able to quantify this particular utility or use for the entity. However, this valuation method only reflects the monetised aspect of the worth of that entity, and not the wider environmental costs of extracting the tree, or any other values that might be associated with it.

Intrinsic values attempt to capture the idea of value beyond the utility of something for an individual or society. The entity is valuable in and of itself, although defining and deciding what this value may be places value beyond a human perspective, suggesting that something has a worth that we cannot measure.

Relational values deal with our interconnected relationships with the natural world. For example, while fishing may have a fundamental value for people who are dependent on fish as a source of protein, there is relationship that is formed with the fish and the activity of fishing. This may itself be essential to an individual or a group's sense of cultural identity, as well as strengthening kinship bonds. This can also be true for recreational fishers. While not depending on fish as a food source, there are still individual and collective bonds that are strengthened through the activity of fishing. This in turn informs relationships that people have with the locality where the activity takes place. Issues of ownership, care and protection are raised through developing interactions in a place – whether those interactions are for subsistence or for pleasure. As well as better representing a broader set of people's preferences, relational values allow us to explore the nuances of instrumental and intrinsic values. Instrumental values may simply reflect the strength of people's needs (in materials terms) without explaining what drives those preferences, and yet this is essential to properly understand human-nature interactions, and implement effective, just and sustainable policy (Chan et al., 2012b).

Relational values that reflect the state of someone's eudaimonic well-being should be expected when asking about the importance of place and the contributions it makes to someone's life (Fredrickson et al., 2013).

1.6 Research Locations

Concepts around ecosystem services, well-being and values need to be place-based to carry meaning (Carpenter et al., 2009; Fisher et al., 2009; Amberson et al., 2016). This study focuses on the services and values that are perceived for a number of globally distributed research locations, which are outlined below.

Aldabra Atoll is one of the world's largest raised coral atolls, governed by the Republic of the Seychelles and managed by the Seychelles Islands Foundation (SIF). It is 1066km south west of Mahé, the main Seychelles island. Protected for more than 50 years, Aldabra enjoys World Heritage status for its unique ecosystems and species. The Aldabra giant tortoise (*Aldabrachelys gigantean*), and the Aldabra rail (*Dryolimnas cuvieri aldabranus*), are symbolically important in Seychelles. While there is no permanent human settlement on the atoll, its World Heritage status and conservation successes are important for the Seychellois (Beaver and Gerlach, 1998; Walton, 2014; UNESCO, 2018).

Danum Valley Conservation Area (DVCA) is a 438km^2 protected primary tropical forest in Sabah, Malaysian Borneo. DVCA is one of three fully protected forest reserves within the larger Yayasan Sabah forestry concession. It is managed for nature tourism, research and education. DVCA has high biodiversity and is home to a number of iconic species, including Borneo elephant and orang-utan. While locally less well-known, DVCA attracts international tourists and is used in promotional material for the Sabah. DVCA has no permanent residents, although it has an education centre, and a well-established research base (Marsh and Greer, 1992; Reynolds et al., 2011).

Haibei Alpine Meadow Research Station (HAMRS) is a small research site in the eastern part of the vast Tibetan plateau ecosystem, in Qinghai autonomous prefecture, China. The research base is run by the North-West Institute of Plateau Biology of the Chinese Academy of Sciences (DEIMS-SDR, 2018; NWIPB, 2018). The wider plateau ecosystem comprises largely meadow and steppe, and supports the livelihoods of yak herders in particular. One species here is iconic and economically valuable – the caterpillar fungus (*Cordyceps sinensis*) – while the traditional culture of the area is promoted to encourage tourist visits (Zhao and Zhou, 1999).

Kytalyk Resource Reserve is within the vast tundra biome, located in Russia's largest province, Yakutia, in north-eastern Siberia (INTERACT, 2014). Action from local people gave Kytalyk Reserve its protected status, as the Siberian Crane, 'Kytalyk' (*Grus leucogeranus*), is sacred to them. It represents the sun, spring and kind celestial spirits to the Yakut and Yukaghir people. Although the population is sparse, connections to the land are embedded here, and the ability to fish is particularly important and central to the cultural identity of indigenous groups (Huntington, 2013).

Laegern Forest is a 400ha managed, temperate forest located between the towns of Baden and Regensburg in the Cantons of Aargau and Zurich in Switzerland. A small forest within a wider mosaic of agriculture and urban land patches, Laegern consists of a number of small, privately owned parcels, with the overall management overseen by the Canton foresters. The research area is a 9ha plot within the wide forest, with well-established infrastructure. The forest is typical for the area, with representative flora and fauna. It is an important recreation area with a charismatic limestone ridge walk, and is well-used by local forest school (waldschule) groups.

Lambir Hills National Park (LHNP) is a 6954ha area of protected, highly diverse tropical forest in Sarawak, Malaysian Borneo. It is managed by Sarawak Forestry, and is important for research, with a 52ha long-term research plot, with education and outreach activities in the local area. Its on-site accommodation, waymarked trails and waterfalls attract high numbers of largely local visitors. It is considered to be the most diverse tropical forest but is isolated within a largely oil palm landscape, and is now experiencing species declines. There are a number of indigenous communities living around the forest with whom the site rangers maintain a close working relationship.

Pasoh Forest Reserve is an 1840ha protected area of primary forest within a wider 13900ha secondary and production forest in Negeri Sembilan, Peninsular Malaysia. It is managed by the Forest Research Institute of Malaysia (FRIM), with the core area enjoying full protection as part of a long-term research project. The forest is important for research and education, with outreach activities for local schools, a well-established nature trail, and an arboretum. Although most large mammals are absent, the white-handed gibbon (*Hylobates lar*) is present and the symbol for the forest, and there are sightings of the clouded leopard (*Neofelis nebulosa*). Although Pasoh forest is relatively near to the town of Sempang Pertang, visitors need a permit to enter.

Lake Zurich is a freshwater lake in the north west of Switzerland, with a surface area of approximately 90km^2. The lake is mostly located in and managed by the Canton of Zurich, with small areas in the Cantons of Schwyz and St. Gallen. There is a research station on the lake shore in Zurich, while water quality is regulated and monitored by Stadt Zürich, where the majority of the human population are located. It is an important source of drinking water for the communities around it, and is heavily used for a variety of recreational activities. The lake itself is symbolic for the city of Zurich.

1.7 Interviewees

The interviewees in this study can all be considered as experts for the research sites, and made up of University of Zürich Research Priority Programme Global Change and Biodiversity (URPP GCB) affiliated researchers, site managers, officers and rangers, and research assistants.

1.8 Research Questions

1. Which values do experts express about ecosystem services at individual research sites?
2. Do the patterns of values expressed by interviewees vary by site?
3. Do the patterns of values expressed by interviewees vary by ecosystem service?
4. Do the patterns of values expressed by interviewees vary by interviewee attributes?
5. Are there values that interviewees mention together for discrete services?

1.9 Position Statement

It is important to consider the contexts in which values elicited from the interviews were expressed. These include the research site, the type of service being discussed, and the factors specific to the interviewee.

Firstly it is important to state that I am an outsider for each research site, as I am local to none of them. On the other hand, I am a researcher myself, and so have an insider position within the research programme, and I have also held ranger positions in a number of different, UK based contexts. Although there are points in common, it is likely that my definitions of value, while all drawn from the existing literature, do not necessarily align with the interviewees. There are inherent tensions in location where a number of organisations have influence, and this is sometimes transmitted through the relations between employees on the ground. For example, it may be that for some people, as a representative of either a specific institution, or a particular research programme was problematic. Although I did not experience any resistance because of this, it is still possible that these tensions might be reflected in some interviewee responses.

The interviews were conducted under different conditions. Most were face to face with both researchers and employees in their place of work. Some were carried out in the research location, while others were either at the University of Zurich or another academic institution.

This is an alternative method to quantify information to a more empirical approach, and I acknowledge that for the reasons stated above, the work is subject to bias, as is all data. Bias is reduced in that I conducted most, but not all interviews myself, and did all transcriptions, and text analyses.

2 Methods

2.1 Interview Methods

The texts used in this study are from semi-structured interviews that I conducted with interviewees connected to the different research sites. The interviews took a two-tiered approach, where I initially asked interviewees about how they perceived the provision of ecosystem services at the site. Specifically, I used the Common International Classification of Ecosystem services (CICES (Haines-Young and Potschin 2012)) to ask interviewees whether each of the 48 described services was present or absent at the site. I also asked interviewees to rank the importance of those services that they considered to be present (low, medium or high, 1-3). This provided quantitative data on perceptions of ecosystem service provision that has been analysed elsewhere. However, the interview procedure allowed me to use the questions as prompts to gain further knowledge about the contributions interviewees felt the research areas made to their and other's lives. These answers often included statements about how the interviewee felt about aspects of the research site. I have used these statements expressing the worth of the location in this chapter to have a better understanding of what is important to people.

I recorded and transcribed a small number of interviews, but for most of them I noted interviewee responses by hand. A small number were also completed in writing by the interviewees, specifically for the Chinese site. The questionnaires were professionally translated into Russian, Chinese and German. I translated one written response from the Russian site, and two Chinese colleagues translated the written responses from the Chinese site. A Swiss German speaking colleague came with me to conduct three in-person interviews for the Swiss forest site, where we both made notes in German and English. We jointly translated her notes into English after the interviews.

2.2 Ecosystem Services

While there are 48 services in CICES V4, for most interviews some ecosystem services were collapsed in to one question to avoid repetition and in some cases to simplify the terminology (table 1). Two services had no values ascribed to them, leaving 38 ecosystem services for inclusion in this study; ten cultural services, 11 provisioning, and 17 regulating.

ESV	Description	Reason for exclusion
01	Experiential use of plants, animals and land-/seascapes in different environmental settings	Combined with 02: Physical use of land-/seascapes in different environmental settings
16	Plants and algae from in-situ aquaculture	Combined with 17
18	Surface water for drinking	Combined with 19
19	Ground water for drinking	No values ascribed
23	Surface water for non-drinking purposes	Combined with 24: Ground water for non-drinking purposes
25	Plant-based resources	Combined with 26: Animal-based resources
28	Bio-remediation by micro-organisms, algae, plants, and animals	Combined with 29: Filtration/sequestration/storage/accumulation by micro-organisms, algae, plants, and animals
30	Filtration/sequestration/storage/accumulation by ecosystems	No values ascribed
41	Pest control	Combined with 42: Disease control
43	Weathering processes	Combined with 44: Decomposition and fixing processes

Table 1: List of ecosystem services not included in this study. 01 is a cultural service; 16, 18, 19, 23 and 25 are provisioning services; and 28, 30, 41 and 43 are regulating services.

2.3 Value Types

As discussed above, Jax et al. (Jax et al., 2013) discuss four value types – instrumental (valuable as a means to something else and replaceable), inherent (beings for their own sake, to which humans have a moral obligation), fundamental (meeting the basic conditions for human life) and eudaimonistic (basic conditions for a good human life). The later work of Chan et al. further defines these as what I have understood to be three over-arching value dimensions – instrumental, intrinsic (both falling into a more traditional paradigm, (McCauley, 2006)), and relational (Chan et al., 2016). This third group captures most of the values that Jax et al. consider inherent and eudaimonistic. Detailed definitions for each code, and its sub-codes, are given below.

2.3.1 *Instrumental values*

Interviewees refer to use of the system or elements of it as a means to something else.

Instrumental:knowledge

Scientific, educational or knowledge based use of biota or system to aid human understanding and knowledge. Includes media use to provide public information, and genetic material for research.

Instrumental:materials

Extraction and use of materials from the area, including for trade and monetary exchange. Includes mentions of food and medicine produced or collected for sale, rather than directly consumed. Mentions of hunting for control are included in this code.

Instrumental:pleasure

Recreational use of the system or biota that gives pleasure and allows people to be in nature. Includes tourism, recreational activities, entertainment, views and hobbies.

Instrumental:subsistence

Extraction of elements of the system that help us to live. General dependence on the system or some part of it in order to live, is coded here. Ingestion of resources (biomass or water) and filtering of pollutants are included here. General cycling of nutrients or GHG that are not specifically described in relation to survival are not included. Crops are included here.

2.3.2 *Intrinsic values*

Interviewees refer to an importance external to human needs and by definition intrinsic importance implies non-human value. They may mention the existence of the system or part of the system and may describe some element relating to importance to itself. This includes the system being left alone or untouched, and simply existing.

Intrinsic:function

Processes and cycles that contribute to ecosystem functioning as part of the basic life support system of earth but not directly linked to human well-being. This may include simple lists of organisms that contribute, for example in pollination and seed dispersal processes.

Intrinsic:special

Uniqueness, specialness but not protection as this is a moral choice taken by humans and is therefore a reflection of the ethical choices made by groups. Intrinsic value may be a reason for protection. This value type includes descriptions of cleanness, being pristine or rarity.

2.3.3 Relational values

Interviewees mention an emotion, a motivation, or a behaviour change. They describe symbolic associations or connotations, or talk about engagement, action, or ownership. This value encompasses the sense of a direct 'relation' to the location.

Relational:cohesion (*social cohesion* in the following text)

Encompasses interpersonal relationships and care for other humans. Includes references to learning, and knowledge for information exchange. Story telling, and the transference of historical and cultural information, such as namings that derive from ecological phenomena (Yung et al., 2003). Opportunities for people to come together, in groups or clubs, or to engage in hobbies, as well as communication, gift giving and reciprocity are within this code.

Relational:eud (*eudaimonic*)

Eudaimonic relationships with place are expressed through a sense of caring and fulfilment. Articulations of making life better, care for place, awe and beauty are encompassed in this value type. Also descriptions of the specialness of place or components of it are coded here.

Relational:identityall (*group identity*)

Elements of the system that are connected to cultural identity, or that define a group. Locally owned cultures of nature, historical and/or cultural significance to a particular group, myths and stories related to a particular group. Traditions, rituals and symbols are included here.

Relational:indiv_id (*individual identity*)

Expressions of how people define themselves in relation to place. Includes articulations of self-understanding and connection, significant or influential educational experiences and the opportunity to develop specific skills.

Relational:moral (moral responsibility)

Ideas about right actions and social norms embedded in instruments. Interviewees describe moral responsibility to non-humans, embodied in references to following rules, principles and policies around justice and equity. These may also be religious principles.

Relational:socialresp (*social responsibility*)

Caring for place as a means to care for other humans. In general, responses to the final question about the relevance and importance of *Bequest* (*"Is it important to*

preserve the area for future generations?") have been coded here, as it refers to responsibilities for future people.
Relational:virtue
Statements that reflect the kind of person an interviewee perceives they should be (rather than this is a right action), making them a good (virtuous) person. May also include social norms but not embedded in instruments. Includes a broad recognition of the worth of place when people express the idea that it is a good thing but how or the amount of value is not specified.

What might be seen from these code descriptions is that there is some inevitable double coding. In some cases there is clear similarity in the codes, for example if a place is described as special, that may suggest intrinsic value (*special*) but it can also be relational for the interviewee (*virtue*), who feels the place is generally of value. It is also clear that in some cases responses can have multiple codings because places or elements of place can encompass multiple values. For example:

> *"It's fascinating. We met this lady at the conference and she had this wonderful necklace, an old one, really a traditional one, made of mammoth bones. Done in such a fine way. So you can see the traditional value to them, these mammoth bones jewellery."* (kes_07)

This statement demonstrates communication between the interviewee and the wearer of the necklace, where the interviewee appreciates and understands something of the wearer's culture grounded in the traditional necklace (*social cohesion*). However this also hints at the importance of the necklace for the wearer herself, connecting her to past traditions and continuing culture (*individual identity*), and also links her to a wider group of people who share a cultural history, rooted in carved mammoth bones found in the area under discussion (*group identity*). So we can see, a necklace is not simply a necklace but embodies multiple meanings, or relationships. All definitions are based on (Chan et al., 2012b, 2016; Jax et al., 2013)

2.4 Coding

2.4.1 Qualitative Content Analysis

To discover the types of values that interviewees reveal when discussing ecosystem services, I used Qualitative Content Analysis (QCA) to assign categories of value within the interview texts. QCA is a technique developed by Mayring (Mayring, 2014, 2015) that allows the use of mixed methods for text analysis. It places categories at the centre of the procedure that should be pilot tested before application to all data/text.

Following the procedure outlined in figure 1, my analysis was aimed at identifying the different types of values that interviewees expressed about ecosystem services, as described in the literature, and discussed above. Therefore the communication context of my analysis is the interviews about ecosystem services at specific sites, which are not open, unstructured dialogues. Although there are other meanings and information in this material, I am here only interested in the formulation of ideas around values, as defined in the ecosystem services literature.

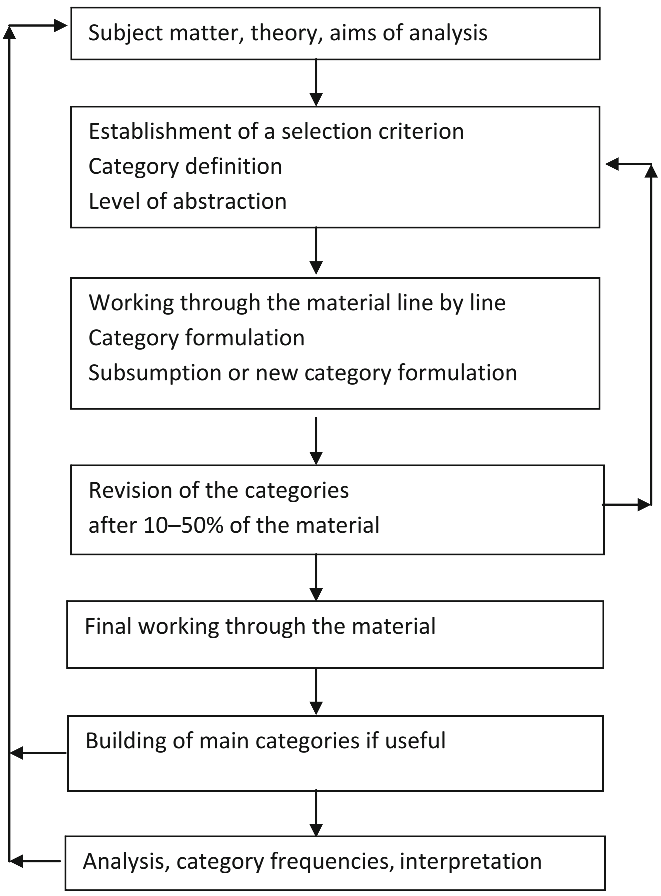

Figure 1: Process model of inductive category formulation, from Mayring 2015.

As I already knew the categories that I wanted to describe from the interviews, my approach is deductive, and determined by the values literature. For the second step of the procedure, this provides group definitions, and the criteria for selecting text that represents particular values.

I could then work through the first interview and search for text where the interviewee mentions language related to the selected values. For example, I might look for instrumental values related to goods and materials that were used for subsistence or pleasure, including extraction and use of material parts of the system. Within this broad group, I might instead find a description of the exact activity, or simply of the species as a direct answer to a question about use. For example, when asked about collection of wild animals as a provisioning service, interviewees gave examples of the animals used. In these cases I assumed this as an instrumental value. Consequently, question context (the type of ecosystem service being discussed) was included in the text analysis. I followed the same procedure for finding expressions of intrinsic value and relational values.

Once I had coded two or three texts in this way, as Mayring suggests, I then assessed all the text examples for each group to check for consistency and overlap. I could also at this point extract anchor examples from my texts for each group which could be later used to ensure consistency of codes in the remaining texts, and which I use as examples.

This step of the process also allowed me to develop sub-categories for each value type in order to be more specific about the values being expressed and to delineate between categories. For example, the definition of *pleasure* as an instrumental value can be rather similar to a definition of eudaimonic value for leading *"a good life"* (Chan et al., 2016) or the *"basic condition for a good human life"* (Jax et al., 2013). I could therefore define *instrumental:pleasure* responses where individuals described being active in the space or using it for recreation and giving them pleasure (e.g. *"I like…"*), and I could also include use of the area by various media for entertainment. However, if individuals then mentioned emotional connections beyond liking something or getting pleasure from it, I coded this as *eudaimonic* value. For example, someone might say how their life is *"better"* with (or *"worse"* without) it, describe how it makes them *"feel good"* or talk about a sense of *"awe"* or *"beauty"*, responses that are more emotionally nuanced.

Some of these definitions for types of value were rather clear in the literature, as the example above illustrates. Relational values have seven distinct types that are well described, particularly as they are partly developed through a desire to advance the dichotomy between instrumental and intrinsic values. However I found some overlap between intrinsic value in general and Jax's definitions of inherent and fundamental values. I therefore also created sub-categories that broadly account for this overlap. For example I created *intrinsic:function* as a code for instances where interviewees describe how the system functions without any direct reference to benefits for people. This was especially useful for capturing some of the information provided around regulating services, as many interviewees clearly understood the importance of the ecosystem functions without needing to explain how these directly impacted human well-being. This value type largely fulfils Jax's definition of fundamental values: "*basic conditions of existence and life on earth*". This iteration of the text coding was essential for developing clear rules and examples for each code that I used.

I initially tried to include NEP (New Ecological Paradigm) (Dunlap et al., 2000; Anderson, 2012) and Dooyeweerd (Gunton et al., 2017) but these were unclear, difficult to find in texts and are less current in the literature. I have found NEP to have a more north American approach, while Gunton's work, based on Dooyeweerd is rooted in a different philosophical tradition. It is however, directly related to other work in the ecosystem services literature but did not, in this particular study, significantly expand the value dimensions. I also took extensive advice from Professor Kai Chan for a better understanding of relational values and the possible points of overlap with other value types. These discussions also enforced the idea that any of the value types described are not fixed and prescriptive, they rather simply help us to be inclusive of multiple viewpoints for a better understanding of what place means to different people. In this vein, it is perfectly acceptable to posit new framings, as long as the definitions are clear in the context of current discussions.

3 Results

3.1 The Values Experts Express for Ecosystem Services at Individual Research Sites

I coded 102 interviews for any mentions of the three broad families of values (instrumental, intrinsic, relational) described above and recorded 2435 references to value. Interviewees most frequently express instrumental values (1469 times, 60.33% of responses), relational values are mentioned 501 times (20.57%), and intrinsic 465 times (19.1%) (figure 1).

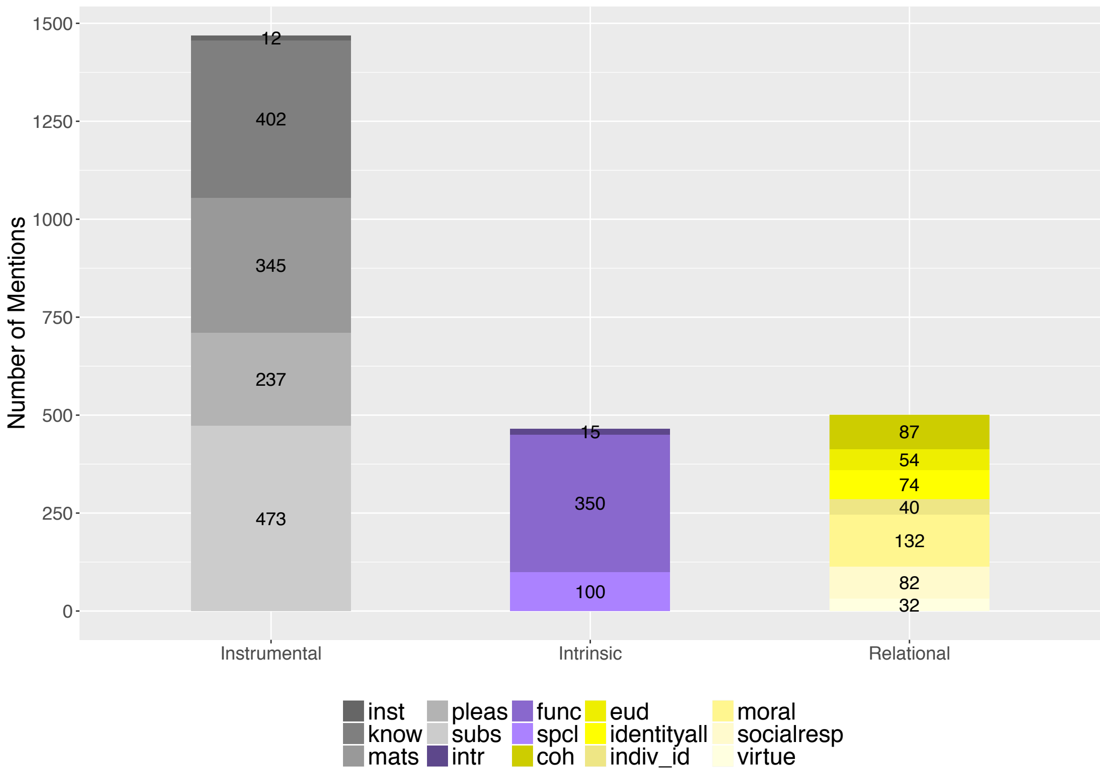

Figure 1: The total number of values that are mentioned by 102 interviewees in each group of values. The grey shaded bar represents instrumental values (total=1469); purple represents intrinsic values (total=465); and yellow represents relational values (total=501). The shading in each bar illustrates responses in sub-categories.

3.1.1 Instrumental values

Three of the four sub-categories of instrumental values make up 83.05% of all instrumental values mentioned. Almost a third (473, 32.2%) are references to uses connected to *subsistence*: interviewees talked about the importance of crops and wild food as food sources, of the system for providing clean air and water, and the collection and use of medicinal plants. The value of the sites for providing *knowledge* make up a further 402 references (27.37%), with interviewees frequently mentioning collection of data for research, disseminating information through various media, and as repositories of historical information. References to extraction and use of *materials* are also high, with 345 (23.49) mentions. These include references to economic use of products of the system (timber, tourism income), use of biomass for fuels and fertiliser, and crop pollination. Interviewees also reference *pleasure* 237 times (16.13%), and there are 12 (0.82%) instances not coded to any value type. *Pleasure* includes descriptions of recreational and tourism use, or of how the site makes the surroundings more pleasant. The uncoded mentions include generalised references to value, to transport and to tourism, without any extra information that can attribute them directly to a value type.

3.1.2 Intrinsic values

The majority of references to intrinsic value are coded in the *function* (350 or 75.27%) and *special* (100 or 21.51%) sub-categories. References to functions describe the role that elements of the ecosystem have in the wider system, for example tortoises as ecosystem engineers. Comments indicating that the location is *special* describe, for example, its uniqueness or rarity of species. These references do not allude to people and how they might benefit from this role or element. There are also a small number of responses (15 or 3.24%) that are not coded to either value type but stated that the location exists, is important, or is untouched by people.

3.1.3 Relational values

The type of relational value with the most mentions is *moral responsibility*, with 132 (25.89%) comments. Here interviewees talk about behaviours that are affected by rules and regulations. For example, burying waste catch from subsistence fishing to avoid accidental supplemental feeding of sharks, or restricting hunting and fishing activities within protected areas.

Social cohesion, *social responsibility* and *group identity* have similar numbers of responses (87, 17.06%; 82, 16.09%; and 74, 14.51%), respectively). Comments about *cohesion* include the common local practice of adding items to the most northerly tree in Kytalyk, providing information for schools and other visitors to the Laegern ridge, or local events held on and around Lake Zurich. *Social responsibility* encompasses the need to preserve Danum forest to protect people’s livelihoods, or to protect the water source for downstream populations dependent on water from the Tibetan Plateau. References to *group identity* are often related to group traditions, describing Aldabra as definitive for the Seychellois or practices unique to the Iban people around Lambir Hills.

There are 54 (10.59%) responses coded for *eudaimonic* values, with interviewees describing amazement and 'once in a lifetime' experiences for people visiting Aldabra, or being lucky to live in or near the forest in Danum and Lambir.

Finally, *individual identity* and *virtue* have 40 (7.84%) and 32 (6.27) coded responses. Indications of value for *individual identity* include descriptions of how individuals dress, or the possibility for farmers to learn and practise traditional skills around Laegern. *Virtue* is illustrated through interviewees describing looking after Haibei, for example, because it seems to be the right thing to do, or the need to build awareness of the wider importance of the forest at Lambir, regardless of legal instruments.

3.2. How Patterns of Values Vary by Site

When references to value are partitioned by site, there are clear differences between them (figure 2a). As there are different numbers of interviewees for each site, the absolute scores give disproportionate results, with Haibei having the most responses and Danum the least. When the proportion of responses relative to the number of interviewees per site are calculated, Kytalyk has the highest proportional number of references to value (35.85), followed by Aldabra (34.87), Laegern (33.45) and Zurich (32.2), while Haibei has the least (14.93). Lambir (24.99), Pasoh (21) and Danum (19.71) increase relative to the number of mentions at the other sites (figure 2b). All sites have more mentions of instrumental values than any other family, and in general, interviewees reference intrinsic values least often. For all sites, references to intrinsic value are mostly related to ecosystem functions. Only Danum and Haibei have more mentions of intrinsic than relational values, and for Aldabra and Zurich the proportions are very similar to relational values (23.78% and 22.36% respectively).

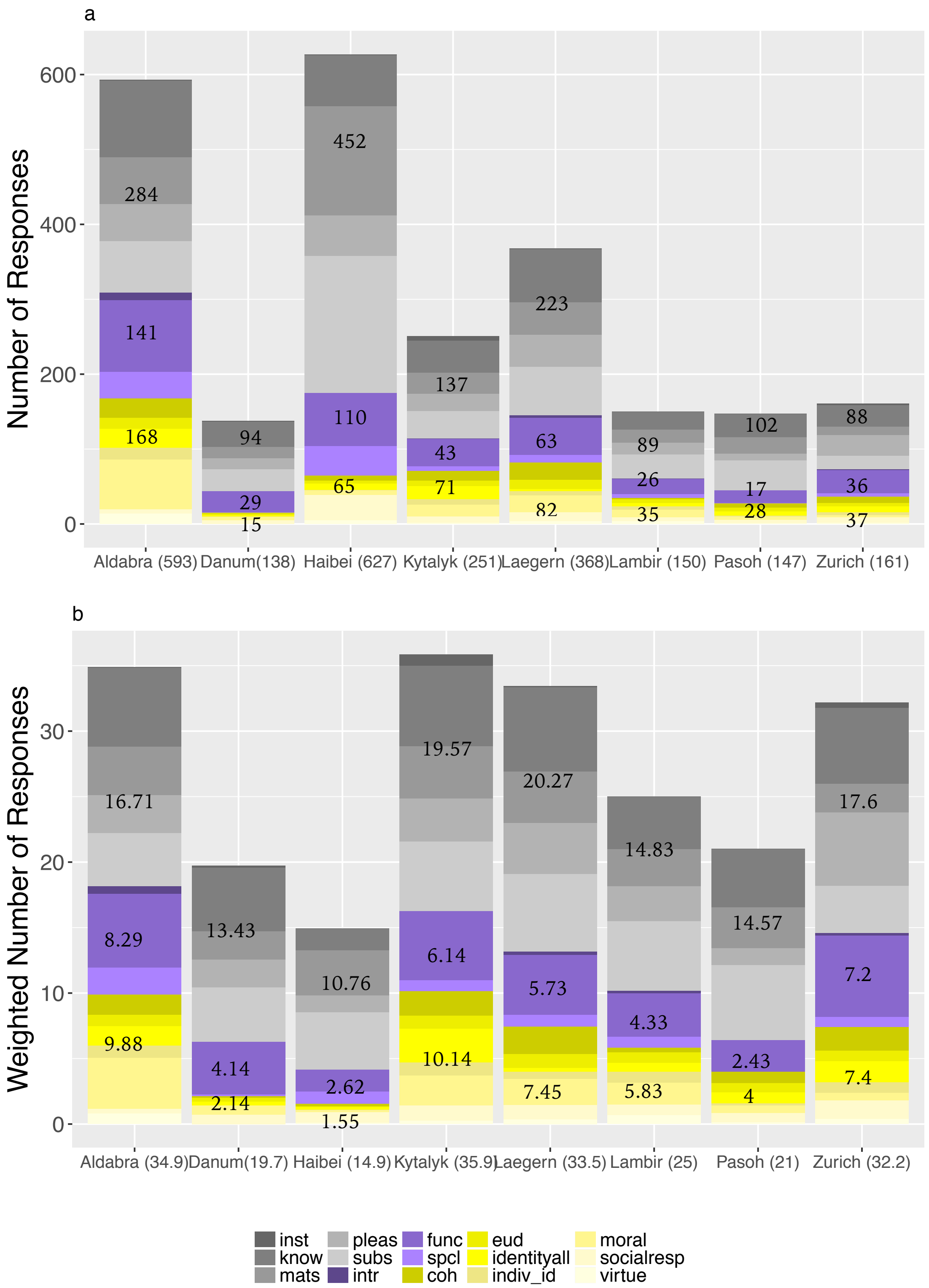

Figure 2: Responses by site and type of value. Figure (a) shows the absolute number of responses, (b) the proportional number (absolute number divided the number of interviewees per site (17, 7, 42, 7, 11, 6, 7, 5, respectively)).

While interviewees at all sites express more instrumental values than either intrinsic or relational, the proportions are different.

Aldabra is the only site where less than 50% (47.89%, see figure S1 in Appendix 6) of the responses are related to instrumental values. Intrinsic and relational values make up roughly equal proportions of the remaining responses. Of the relational values, interviewees mention *moral responsibility* most frequently. Over two thirds of the values I recorded from Danum are instrumental (68.12%) and only five of the seven relational values are represented in the interviews for this site. There is also only one mention of the intrinsic value *special*.

A large proportion (72.09%) of responses from Haibei mention instrumental value, the highest of any site. There is a large proportion of references to *subsistence* value for the site, and most relational values are references to *social responsibility*. Interviewees from Kytalyk often express relational values (28.29%), although less frequently than instrumental values. All possible value types are mentioned here, with the exception of the general *intrinsic* value type.

Interviews about ecosystem services at the Laegern site elicit all value types, with 60.51% assigned to instrumental values. *Social cohesion* and *moral responsibility* are mentioned most frequently for the relational values.

59.32% of the values recorded for Lambir are instrumental, while 23.33% are relational. There is a relatively high number of mentions of *subsistence* value, and *moral responsibility* is the most frequently mentioned relational value.

Instrumental values make up 69.38% of the responses from Pasoh, with very few references to intrinsic value.

Lake Zürich elicits all value types, and 22.98% of those are relational values.

A Chi-squared test to identify whether the differences between the site responses are greater than would be expected if all sites were the same, gives a very low p-value (X-squared = 114.22, df = 14, p-value < 2.2e-16), suggesting that the responses do vary depending on which site they are describing. As the above outline suggests, there are some similarities in the general pattern – most values expressed are instrumental – but the distribution of values is different for each sites.

3.3 How Patterns of Values Vary by Ecosystem Service

The questions that elicited the value types are framed around ecosystem services. Investigating whether different values are expressed in relation to different ecosystem service sections and different ecosystem services is therefore also interesting. In this analysis, one interview was removed because it was sent as a written text and not framed around specific ecosystem services and sections (aes_01). This gave a total of 101 interviewees with 2416 responses.

3.3.1 Ecosystem service sections

From this overall number of mentions of value, 973 (40.27%) responses are from questions about cultural services, 783 (32.41%) are from provisioning services, and 660 (27.32%) from regulating (figure 3).

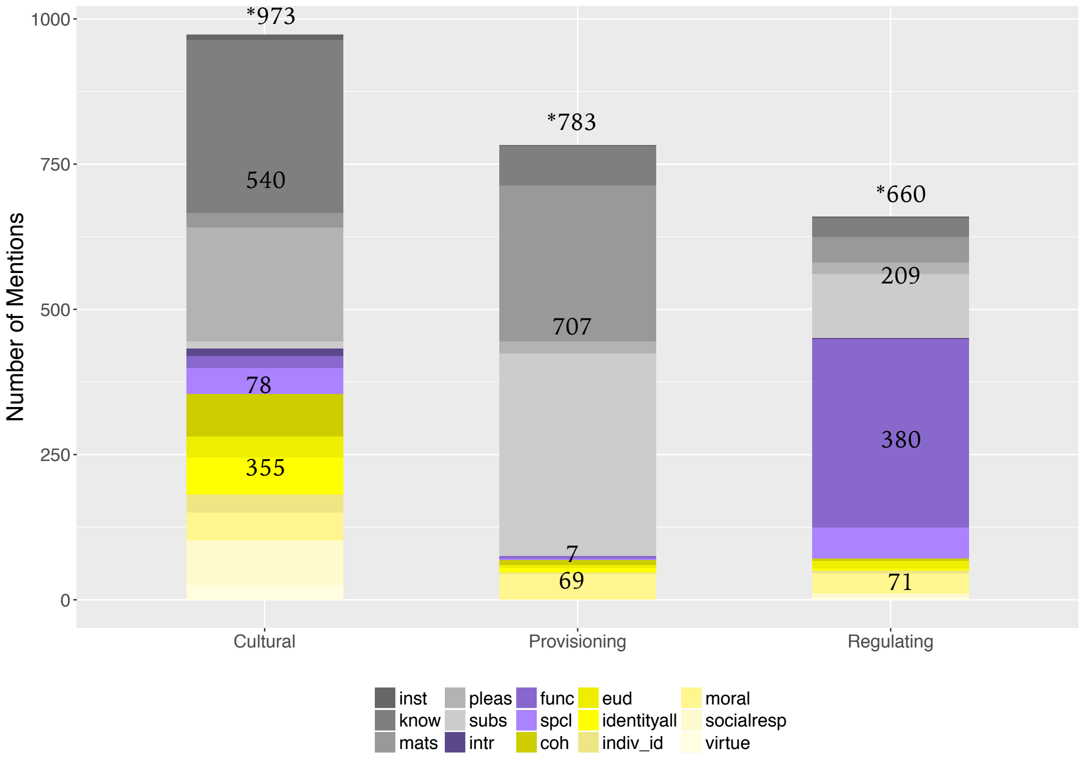

Figure 3: Number of responses for each value type for the three ecosystem service sections – cultural, provisioning and regulating.

Within the sections, the broad categories of values (instrumental, intrinsic, relational) are distributed differently.

Across the 10 cultural services, instrumental values make up more than half of the responses, while over a third are relational values, and intrinsic values make up just 8.02% of responses.

For the 11 provisioning services, this pattern is more exaggerated. There are 707 mentions of instrumental values and these make up over 90% of all values conveyed by interviewees in this service section. Individuals state relational values in only 8.8% of cases and intrinsic values make up just 0.9% of responses.

The 17 regulating services elicited fewer responses overall (660), with almost 60% related to intrinsic value (57.57%). A third of responses express instrumental value (31.67%) and the remaining 10.76% are given to relational values.

If I account for the different numbers of services in each section (10, 11 and 17 respectively), the spread of values across the services becomes less even. Cultural services elicit proportionally more responses, with 46.94% or 97.3 mentions per service. This is more than the 34.34% elicited from provisioning services (71.18 mentions per service), and well over double the number of values mentioned for regulating services (18.77% of all values, or 38.82 per service).

When adjusted to the number of services in each section, cultural services clearly elicit the most references to relational values (77.26%), while regulating services elicit the by far the most expressions of intrinsic value (72.61%). Provisioning services elicit the most references to instrumental values (49%), although this is not much higher than the amount from cultural services (41.17%). Provisioning services also have very low proportions of either intrinsic or relational values (2.05% and 13.65%). Proportionally, interviewees reference instrumental values more than four times as frequently as intrinsic values and about three times as often as relational values.

The service sections are further differentiated by the value types that are most frequently represented in each. The instrumental values elicited from questions about cultural services are mostly those related to *knowledge* (298 references) and *pleasure* (196), while instrumental values for provisioning services are predominantly *subsistence* (348) and *materials* (269). Most references to instrumental values from regulating services are *subsistence* (110). Intrinsic values are chiefly made up of those connected to ecosystem *functions* for regulating services (324), while intrinsic values expressed for cultural services are mostly related to how *special* the location is(44). Provisioning and regulating services both more often elicit ideas about *moral responsibility* (44 and 34 respectively), however, cultural services promote references to *social responsibility* (76), *social cohesion* (74), and *group identity* (63).

These observed differences seem quite well-differentiated, but to test whether they are significant I ran a chi^2 test on the raw data, which returns a very low p value (X-squared = 1119.1, df = 4, p-value < 2.2e-16), suggesting that the values are distributed differently within the ecosystem service sections.

3.3.2 *Discrete ecosystem services*

The previous section showed that cultural services elicit the most values but I wanted to know if there are individual services that evoke more values than others. I therefore looked at how many of the fifteen discrete value types are expressed for each ecosystem service (figure 5).

There are two provisioning services (ESV16 and ESV25) that never have any values assigned to them, and the 38 remaining services are coded with at least three values across the interview texts. The distribution of the number of values coded to services is shown in figure S2 in Appendix 6.

Six of the eight services with ten or more values are cultural (physical and experiential use (ESV02), heritage (ESV05), aesthetic (ESV07), symbolic (ESV08), existence (ESV10), and bequest (ESV11)). The remaining two are regulating (mediation of noise and visual impacts (ESV32) and maintaining nursery populations and habitats (ESV40). As I expected, cultural services elicit a wider range of values than regulating or provisioning services.

Most cultural services also have a high abundance of values assigned to them, however, two have rather low totals, despite a range of values. Scientific (ESV03) with 53 values across seven sub-categories; and sacred and/or religious (ESV09) with 49 values over nine sub-categories.

Some provisioning services have very high abundances, if not diversity. These are all related to nutrition – drinking water (ESV24), collection of wild animals (ESV15) and wild plants (ESV14), cultivated crops (ESV12), and reared animals (ESV13).

In general, regulating services elicit lower numbers of values, however some still exhibit a range. For example, while I coded ESV32 for ten of the different sub-categories, I only coded it 33 times. Interviewees infrequently expressed a value for this service, and when they did the type of value given varied widely.

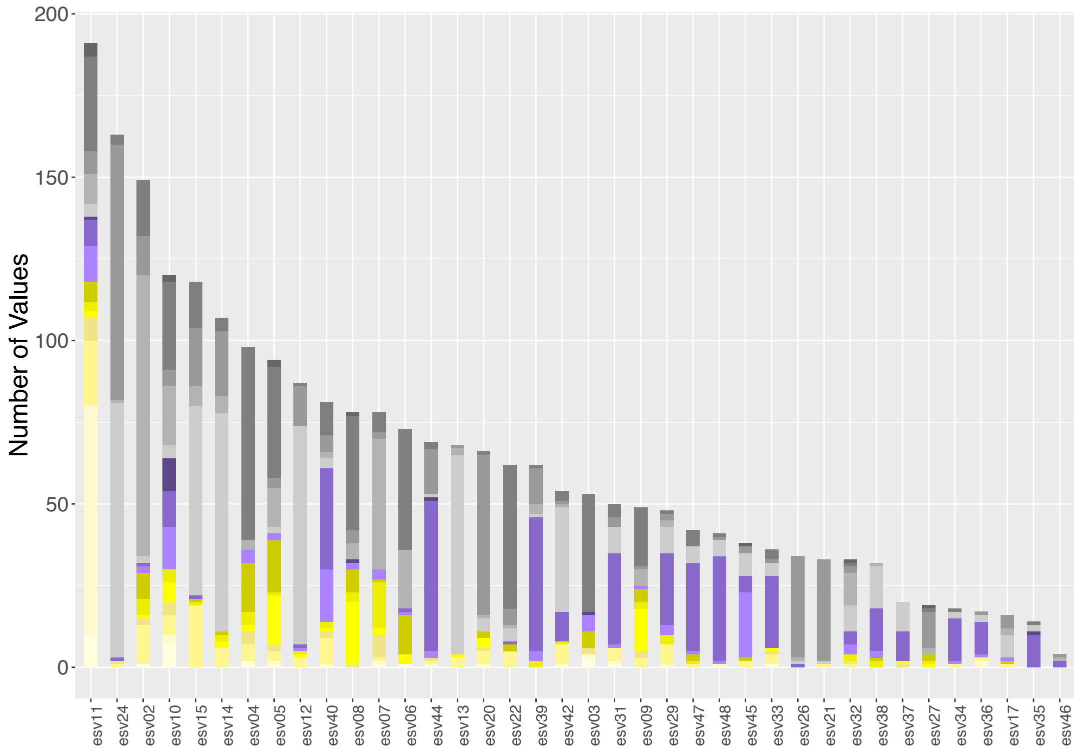

Figure 5: Number of values for each of 38 ecosystem services. Grey shading = instrumental values; purple = intrinsic; yellow = relational.

Finally, there are a small number of services that have one predominant value assigned to them. ESV13 is largely linked to *subsistence* value, ESV21 (materials from plants, algae and animals for agricultural use) and ESV26 (animal-based resources) have mostly *material* value given to them, and ESV48 (micro and regional climate regulation) is largely connected with *function* value.

3.4 How Patterns of Values Vary by Interviewee Attribute

While interviewees mentioned instrumental values most frequently, there is variation in the types of values that individuals expressed during the interviews (figure 6).

In absolute numbers, two interviewees reveal proportionally more values than others. Interview kes_07, which I recorded and transcribed, makes 77 references to values; and les_07 (written notes) makes 60 references. More than half of the interviewees (54) express some form of value at least 20 times, leaving 48 people who mention value fewer than 20 times. Of those 48 interviewees, the majority (38) are written responses by the interviewees and not face-to-face interviews. Thirty-six of these are from the Haibei site, with one written response each from Kytalyk and Aldabra. I coded the responses of only one interviewee for all value types, and a further 30 people expressed at least ten of all fifteen values. Figure S3 in Appendix 6 further illustrates the diversity of values revealed by interviewees.

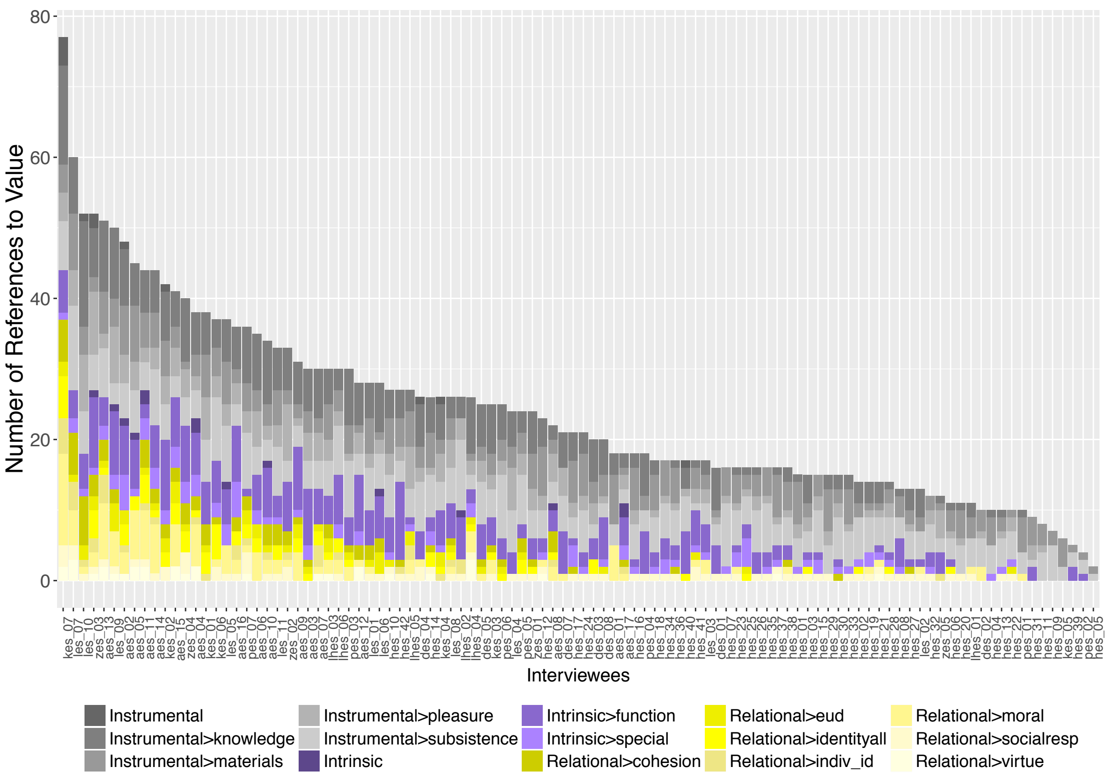

Figure 6: Total number of references to value from all 102 interviewees. Grey shading = instrumental values; purple = intrinsic; yellow = relational.

A linear model further illustrates that interviewees who frequently mention any value also express a range of value types (figure 7). (F-statistic: 307 on 1 and 100 DF, p-value: $< 2.2e\text{-}16$, adjusted $R^2 = 0.7518$).

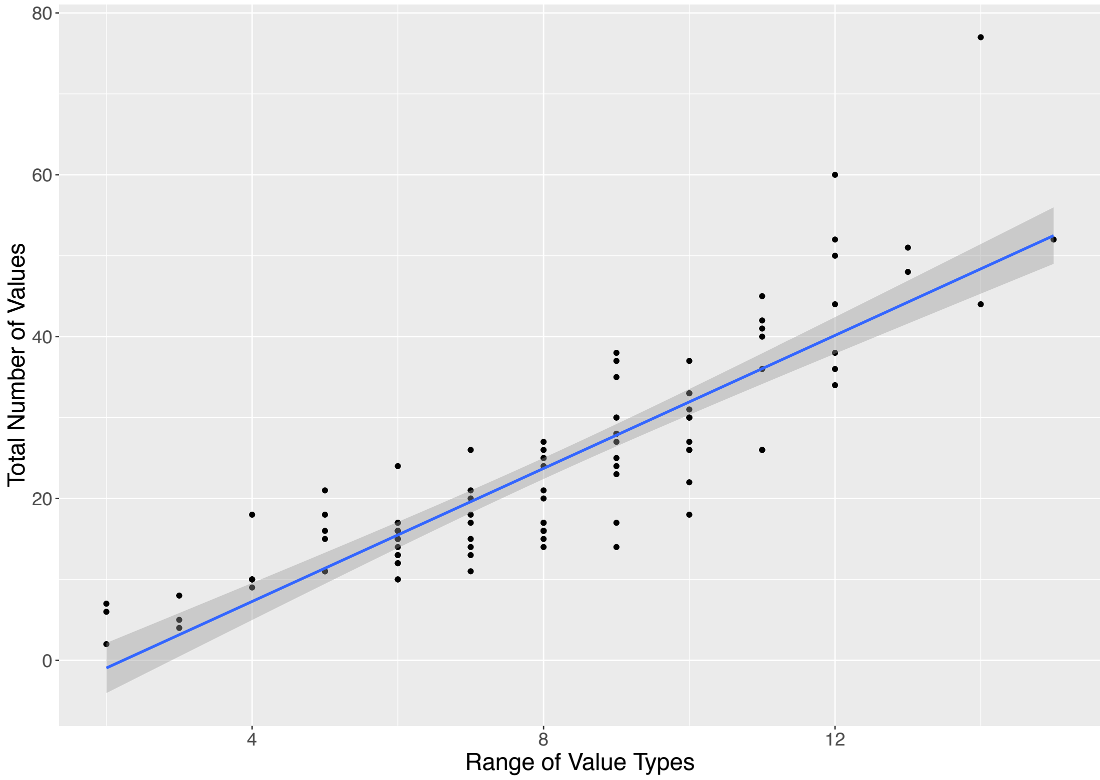

Figure 7: Relationship between the number and range of values that interviewees mention. Regression line indicates a linear relation.

To determine whether there were other factors that might explain which and how many values people expressed, I then explored the attributes of the interviewees.

Occupation

(Appendix 6, figure S4)

Ninety-eight interviewees provided information about their occupational status and when the response rate is corrected for the number of people in each occupation category, I find that academics and site managers reveal more relational values than interviewees in other occupations. Site officers mention a higher proportion of instrumental values.

A Chi² test on the raw data confirms that the responses from the groups differ more than we would expect from random:

X-squared = 27.797, df = 10, p-value = 0.001946

Education Level

(Appendix 6, figure S5)

There are 95 interviewees who gave information about their maximum education level. When their responses are adjusted for the number of people in each group, people who have attended college and high school mention values more than those educated to Master and Doctorate level.

The Chi^2 test on these responses gives:
X-squared = 28.647, df = 10, p-value = 0.001421
This indicates that there is a difference in response depending on education level.

Gender

(Appendix 6, figure S6)
The responses of 101 interviewees are included for analysis related to gender. Once the difference in group size is accounted for, there are proportionally more responses about values from women than from men.

The Chi^2 test on the absolute data gives:
X-squared = 10.253, df = 2, p-value = 0.005938
Indicating a difference in responses between the genders.

Age Class

(Appendix 6, figure S7)
Again, 101 interviewees provided information about their age. The adjusted data suggests that older interviewees mention values more often than younger interviewees.

The Chi^2 test on the absolute numbers supports the observed differences in responses between the age classes.
X-squared = 39.281, df = 8, p-value = 4.36e-06

Factors

In order to reduce the number of values to fewer dimensions, factor analysis on the interviewee data gives four clusters of values from interviewees, and one value, *group identity*, that did not cluster with any others. I ran the same analysis using the range of values assigned to the ecosystem service rather than by interviewee to determine factors but there are not enough levels for this to produce results.

The values roughly align into four groupings based on how interviewees express them (figure 8). Three of these groups are also correlated with one another, while *group identity* is independent of the others.

MR1 – aesthetics and fun

This group of values centres on *pleasure* and learning (*knowledge*) in healthy ecosystems (*function*). There is also an element of being involved in care for place (*eudaimonic*) and building relations with others (*cohesion*).

MR2 – virtue and beauty

Values connected to aesthetics (*special, intrinsic*) and morality (*moral, virtue*) are included here. However this group might be seen as more about personal rather than group values (*individual identity*).

MR4 – this is who I am

Only two values are included here and seem rather to be connected to direct use of place (instrumental) and personal agency (*individual identity*).

MR3 – survival

The final group of values centre rather on values that facilitate necessary (*subsistence, materials*) and responsible (*social responsibility*) use of ecosystems in order to meet human needs.

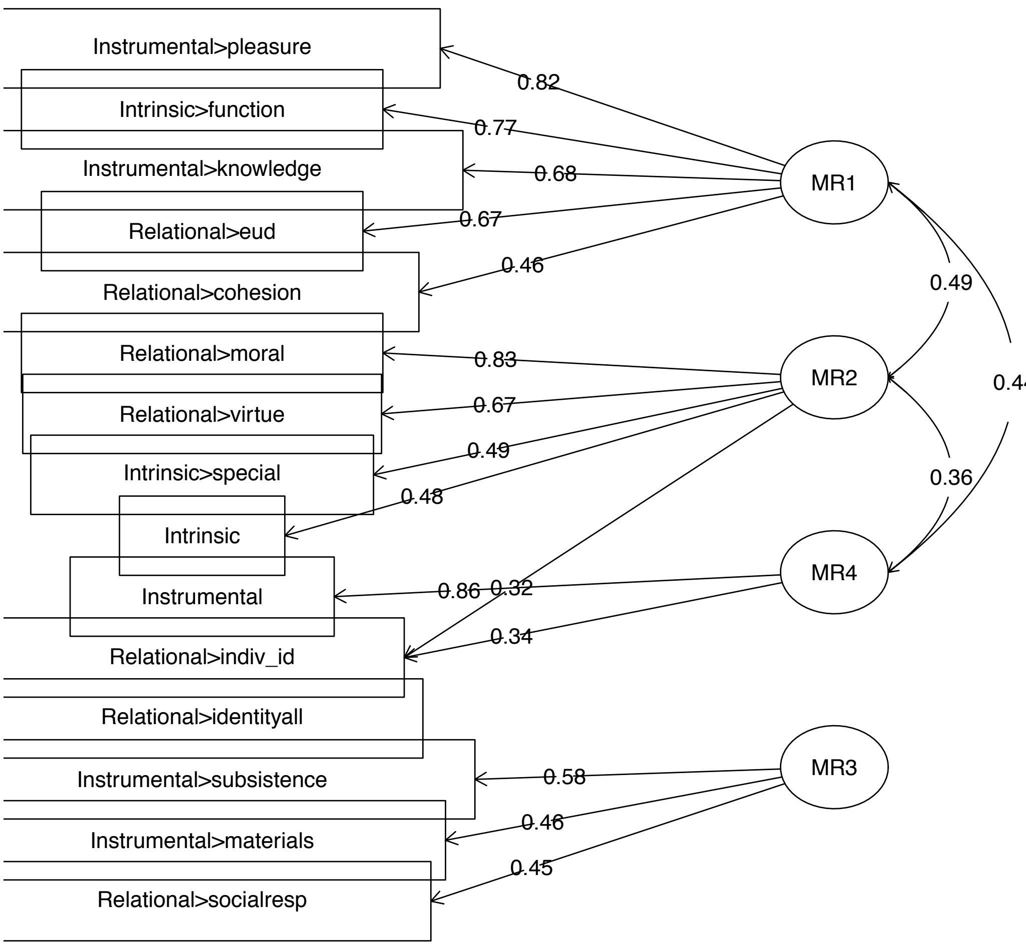

Figure 8: Factor analysis of the values assigned by interviewees. Value types are in the boxes on the left-hand side, Factors groups are denoted by the circles. Numbers on the arrows indicate the strength of alignment within each factor level. Factors MR1, 2 and 3 are also connected. *Group identity* (*relational:identityall*) is not aligned with other values in this analysis.

3.5 Values that Interviewees Mention Together for Discrete Services

Most ecosystem services elicit more than one value type from interviewees across the full dataset. However, some questions about ecosystem services also elicit more than one value from individual interviewees. For example, an interviewee could express both *subsistence* and *eudaimonic* values for drinking water.

3.5.1 Value groups

Across the full dataset, 23 discrete answers elicit all three groups of values (instrumental+intrinsic+relational). A further 325 responses elicit dual groups (instrumental+intrinsic; instrumental+relational; intrinsic+relational) (table 2, figure 9a). Twenty-two responses express instrumental+intrinsic value for the ecosystem service being discussed, 256 responses combine instrumental and relational values, and 24 responses encompass intrinsic+relational values. When these combined value groups are divided between the three sections, 231 (71.08%) are answers to questions about cultural services. Provisioning and regulating services both account for 47 responses (14.46%).

Values	Cultural	Provisioning	Regulating	Total
instrumental + intrinsic	8 (36.36%) (3.46%)	1 (4.55%) (2.13%)	13 (59.09%) (27.66%)	21 (6.77%)
instrumental + relational	189 (73.83%) (81.82%)	44 (17.19%) (93.62%)	23 (8.98%) (48.94%)	256 (78.77%) (259-3*NA)
intrinsic + relational	17 (70.83%) (7.36%)	2 (8.33%) (4.26%)	5 (20.83%) (10.64%)	24 (7.38%)
instrumental + intrinsic + relational	17 (73.91%) (7.36%)	0	6 (26.09%) (12.77%)	23 (7.08%)
Total	231 (71.08%)	47 (14.46%)	47 (14.46%)	325

Table 2: Number and percentage of times I coded responses with two or three value groups. First number in brackets in each cell is the percentage of that code combination in the ecosystem service section, e.g. 36.36% of the 22 instrumental+intrinsic codes are in cultural services. Second bracketed number is the percentage of each code combination for each ecosystem service section, e.g. 3.46% of the 231 code combinations for *cultural* services are instrumental+intrinsic.

When I correct for the number of responses for each ecosystem service section, the relative importance of regulating services for eliciting values from two or three of the groups increases compared to provisioning services, while cultural services become even more important. The triple coded responses are divided between cultural (73.91%) and regulating (26.09%) services, with one in the provisioning services section.

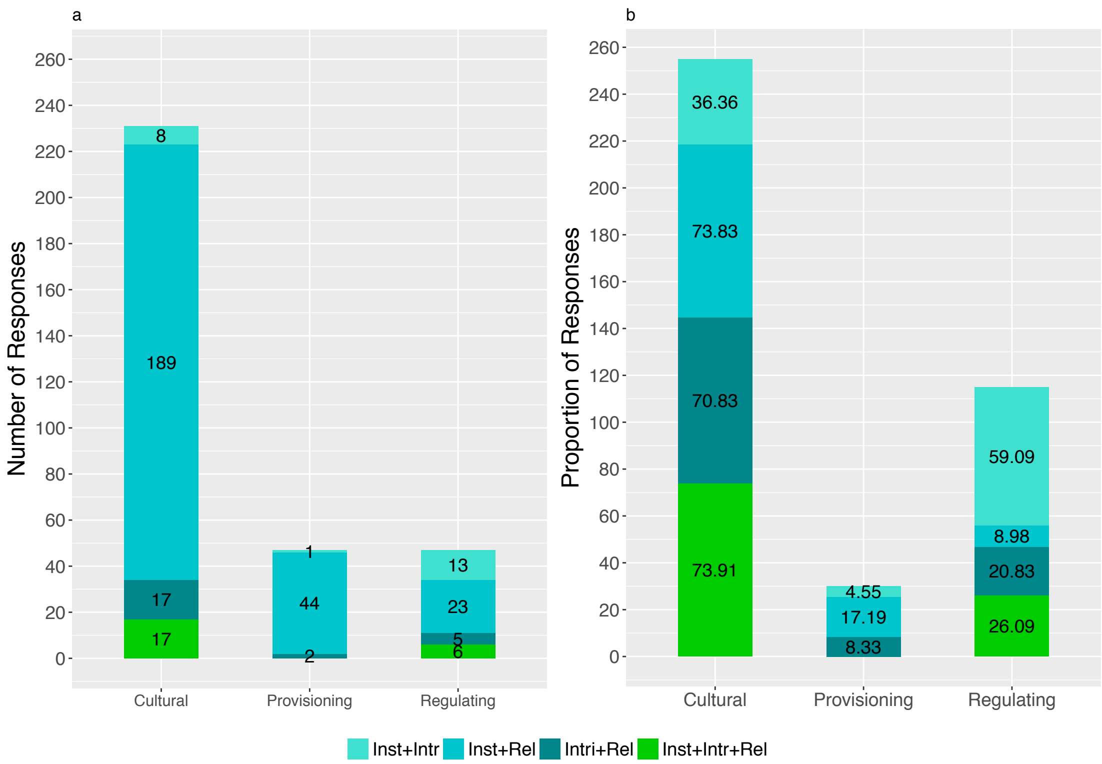

Figure 9: Absolute (a) and proportional (b) number of double and triple codes in each ecosystem service section.

Normalizing to the number of questions in each section (figure S8, Appendix 6), reveals that the 10 questions about cultural services disproportionately elicit high numbers of values, while the 11 questions about provisioning services elicit slightly more mentions of value than the 17 regulating services ones.

3.5.2 Value types

To understand which value types, not just groups, are expressed in discrete responses about ecosystem services, I looked at where there are combined codes between all types of value. This increases the number of instances of two codes being assigned to a single response from 325 across the broad groups to 735 across all value types. I used a simple bipartite network analysis (Dormann and Gruber, 2011) to illustrate these pairwise relationships (figure 10).

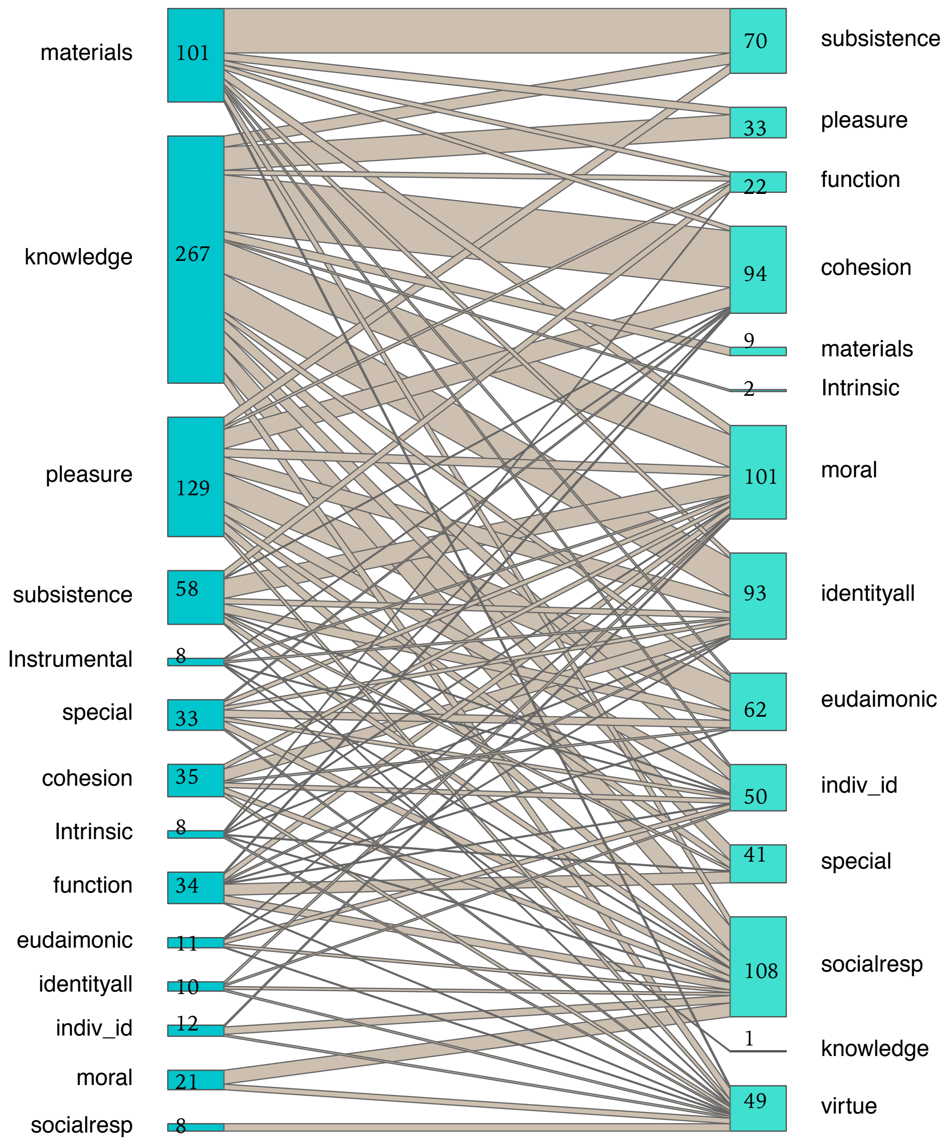

Figure 10: Bipartite network of the value types that occur together in single responses about ecosystem services. Box size and line width represent the number of connections. Numbers on boxes are the total number of connections for each value type, The sum of totals for one side represents the full number of double codes (735).

Four of the five instrumental value types are very frequently coded with other values. *Instrumental:knowledge* has the highest number of links to other values (268), including with *social cohesion* (61), *group identity* (41), *moral responsibility* (35), and *social responsibility* (27). It is coded with *instrumental pleasure* 25 times. *Instrumental:pleasure* (co-coded 162 times) is also coded with *eudaimonic* value 31 times, and with *social cohesion* 21 times. *Instrumental:subsistence* has 128 dual codes, while use of *materials* is coded 110 times. These two value types are coded together 48 times, while *subsistence* value is coded 21 times with *moral responsibility*.

Of the group of relational values, *cohesion* is co-coded most frequently (129 times), followed by *moral responsibility* (122 times), *social responsibility* (116 times), and *group identity* (103 times. Intrinsic values are much less frequently coded with other values.

Cultural Services

Most shared values are found within the ten cultural services, with 505 interactions (68.71% of all combined codings) (figure S9, Appendix 6). *Instrumental:knowledge* has the most co-codings, and is most frequently connected to *social cohesion* and *group identity*. The next most frequent, *social responsibility* has a much more even distribution of dual codes with all other values except *virtue*, while *pleasure* also has relatively evenly distributed codings with nine other values. *Social cohesion* and *group identity* code often with *knowledge* and *pleasure*.

Provisioning Services

There are far fewer code combinations for provisioning services, with the greatest number with and between *instrumenta:materials* and *subsistence* (figure S10, Appendix 6), explaining also why there are fewer dual codes seen between the value categories (figure 8 above). In this ecosystem service sections, the relational value *moral responsibility* does however code frequently with other values, particularly *subsistence*.

Regulating Services

Again, there are few dual codes for regulating services, reflecting that there are fewer values in general mentioned for this section of ecosystem services. However, those that do occur are often across value categories (figure S11, Appendix 6). *Function*, as the most common value assigned to regulating services, is coded most frequently with other values, followed by *subsistence*, *special* and *eudaimonic*.

3.5.3 Individual services

It is also possible discern whether there are services that elicit more than one value type from individuals. One interview was removed as it was not coded for specific ecosystem services, leaving 718 dual codings.

The previous analyses show clearly that cultural services elicit the widest range and highest abundance of values, as well as more combined codes in single responses. All cultural and all provisioning services have single responses that mention two values, as do 14 of the 17 regulating services. Twelve services have more than 20 double coded statements, and all ten cultural services are amongst the 15 services with the highest number of dual codes (table 3).

Service	N	Value 1	Value 2
11	139	social responsibility	+ knowledge, moral, pleasure, special, materials, function, virtue
05	51	knowledge	+identityall, cohesion
10	49	knowledge	+ special
02	48	knowledge pleasure	+ pleasure + cohesion
04	47	knowledge	+ cohesion
07	41	pleasure	+ eudaimonic
08	41	knowledge	+identityall
15	36	subsistence	+ moral, materials
06	33	knowledge	+ cohesion
40	29	function	+ special
09	27	knowledge	+ identityall
14	22	subsistence	+ materials, moral
03	17	knowledge	+ cohesion
20	13	materials	+ moral
27	13	pleasure	+ cohesion

Table 3: The fifteen services with the highest numbers of dual codes from individual responses, given in column N. The value types shown are the most frequent for each service, although each service has other, less common, combinations. Interaction webs for each service are shown in Appendix 6, figures S12-26.

4 Discussion

4.1 The Values that Interviewees Mention

The full range of 15 values are mentioned across the interviews used for this study, suggesting that the value types chosen, and the extensive consideration given to them in the literature, are able to capture different value dimensions. It also shows that there is little or no redundancy in the value types.

However, when people discuss ecosystem services, they mention instrumental (use) values roughly twice as often as either relational or intrinsic values. This is not surprising, as the epistemological position of ecosystem services lends itself to a discourse around these value types (Gould et al., 2015).

In this data, *subsistence* and *knowledge* are the instrumental value types that interviewees reference most frequently. This group of interviewees is predominantly engaged in working with and learning about the systems we discussed, so it is unsurprising that they express the importance of gaining knowledge from the sites. The prevalence of references to a fundamental dependence on the system (*subsistence*) also suggests that this group of interviewees recognise the extent of human dependency on nature.

Despite this emphasis on instrumental values, they are not the only values that are evident here. Intrinsic values are mostly expressed through discussions of ecosystem *function*, largely but not exclusively captured through regulating services. While these may be less clear statements of human dependency on the system, they show that interviewees think beyond human need to the necessity of having a healthy, functioning system.

Relational values are mentioned only slightly more than intrinsic values, with a wider range of value types. The most frequently mentioned of these are *moral responsibility*, *social cohesion*, and *social responsibility*. This can perhaps be explained by site context, since the research sites are protected areas with legal instruments and management systems in place. Interviewees recognise the need to adhere to these rules and obligations in order to maintain healthy systems for now and into the future. As they are also sites where researchers and site officers work together, often alongside the wider community, mentions of values that recognise this are not surprising.

4.2 How Values Vary by Site

This overall pattern of values and services is drawn from the full dataset, and this pattern largely remains for each research site. Most sites had high proportions of instrumental values related to *subsistence* and *knowledge*. While not all support subsistence activities such as herding, fishing or hunting, several do and most have at least some level of wild food collection. Traditional and inter-generational activities facilitate the role of the sites as reservoirs of local and traditional knowledge, as well as for educational and research activities. This explains why *knowledge* is so often mentioned by interviewees. However, values do differ from site to site, reflecting that they are very different ecological and social systems, with varied human populations depending on them. These differences in values are discussed briefly below.

As an isolated and uninhabited coral atoll far from the main islands of Seychelles, Aldabra provides limited opportunities for any resources to be exploited in significant quantities. This may explain the slightly lower number of references to instrumental values. The high level of protection it enjoys probably also explains the even split between *intrinsic* and *relational* values. This protected status confirms Aldabra as a *special* place, and provides a source of pride in how the Seychellois have preserved this it, in part by adhering to a *moral responsibility* to uphold the laws and regulations in place to support this effort.

While Danum Valley is not easy to access, it is nevertheless well-known and attracts international visitors, some of whom are very high profile. This tourism value, as well as some localised dependency on the forest for wild food gathering might explain the high proportion of instrumental values in the responses from here. People depend on it for employment, for some subsistence farming at the edges of the wider forest, and as a water source, for example.

The Haibei research site sits in a vast landscape that continues to support people through subsistence farming, particularly yak herding. Additionally, people gather wild plants, hunt small mammals, and collect the prized and valuable caterpillar fungus (*Ophiocordyceps sinensis*). Again, these dependencies come out in mentions of *subsistence* values. The site is also an internationally important research location, shown through mentions of instrumental *knowledge*.

Subsistence is again important for the Siberian site, Kytalyk, as it provides for people engaged in fishing, reindeer herding, and wild berry and mushroom gathering. These activities are traditional, holding a great deal of knowledge within them that binds groups together. This helps to explain the high number of references to *subsistence* values as well as *knowledge, group identity, moral responsibility* and *social cohesion*. In addition, as an arctic tundra site experiencing higher summer temperatures and increased permafrost melting, people often place value on the ecosystem functions it provides and that are threatened.

Surrounded by agricultural land, near to Switzerland's biggest airport and next to a highway, Laegern forest receives a higher proportions of *subsistence* and *function* values. While these recognise its role in the landscape, *knowledge* values point to its other role as an internationally important research location.

The results for Lambir Hills National Park and Pasoh Forest Reserve are similar, as they both continue to be sources for seeds and pollinators, as well as some fruit bearing trees. This allows people to grow and gather fruit and wild plants, largely from their small-holdings nearby. They are both also internationally important research sites. These roles are reflected in the *subsistence* and *knowledge* values people express about them. The importance of protecting Lambir as an island of forest in a largely oil palm landscape is also suggested by a somewhat higher proportion of *moral* values.

Finally, perhaps more than any other site, Lake Zürich supports a high amount of recreational activity, reflected in the higher proportions of *pleasure* values mentioned. The lake is iconic for the city, providing a common space for people to come together, creating higher levels of values around *social cohesion*, *group identity*, and *social responsibility*.

4.3 How Values Vary by Service

I would expect also that people describe and value each ecosystem service differently, and while some of this is due to the research site itself, it is also because the services perform different functions for people. While there are clear differences in the values given to each research site, there are also differences in the range and abundance of values given to specific ecosystem services. Overall, there are some logical divisions in the kinds of values assigned to ecosystem services.
Firstly, there is a clear division between the three ecosystem service sections. Provisioning services predominantly elicit instrumental values as might be expected from questions that focus on extraction of resources from the system, and how and why people use them. Regulating services elicit discussions of ecosystem functioning, which is here reflected by intrinsic values being dominant for this section of ecosystem services. Cultural services capture more and a greater range of values overall, seeming to equally well capture instrumental and relational values. However, most expressions of relational value are confined to cultural services.

These distinctions do not mean that the value types are exclusive to the ecosystem service section, and many services have a range of values associated with them. Those services that elicit the greatest range of values are largely cultural, meaning that these are perhaps more open to interpretation by the interviewees.

This also supports suggestions from other authors that cultural services are less well-defined (Chan et al., 2012b; Daniel et al., 2012; Satz et al., 2013; Schröter et al., 2014), possibly making them better suited to capturing the connections people have to place, even if these connections cannot be directly quantified. I would therefore argue that it is far more important to recognise that these connections and values exist, rather than to try to count or measure them. Further, it seems to me that these are essential to capture in any ecosystem service assessment, and recognition of the values expressed through cultural services are an essential component of any assessment.

While a range of values is interesting, it is equally important to consider the merit of understanding the services that elicit a high number of values, as this points to services that are easier for people to give value to. This reinforces the importance of capturing values for cultural services as most had both a high range and high abundance. However, it also means that provisioning services are equally relevant. It is clear in this data that those services directly connected to providing food and water elicit high numbers of instrumental values. From this, I not only see which values people place on use benefits, but can also to some extent measure how important services are to them. For example, it is clear that for Lake Zürich, people recognise its importance in providing clean water. While it might already be possible to quantitatively measure this in terms of amount of water provided per head of population, and the costs associated with it, it is equally helpful to observe that the beneficiaries also recognise this.

It is interesting that all services elicit more than one value type, with only two having a single value that accounts for more than 90% of all values given. This is a good indication that trying to assign only one kind of value to ecosystems, functions and the benefits they provide is a narrow and misleading approach that can give an incomplete picture of the benefits people perceive they gain from ecosystems (Klain et al., 2014).

Finally, there are some services across the research sites that have other values alongside the more predictable ones that I expected interviewees to mention. This suggests it might be possible to use some services as indicators for value types, if they are provided at a research site. Service 40 (maintenance of nursery populations and habitats) could be expected to consistently elicit the intrinsic *function* and *special* value types, but people also frequently mention instrumental *knowledge* and *materials*, along with a mix of relational values connected to doing the right thing (*eudaimonic*, *moral responsibility*, and *virtue*). Services 14 and 15 are connected to the hunting and gathering of wild plants and animals, and as again might be predicted, they both always elicit *subsistence* value. However, they also frequently prompt people to express the other three instrumental values (*knowledge*, *materials*, and *pleasure*). People also often give a mix of relational values for these services that are connected to group and moral values (*social cohesion*, *eudaimonic*, *group identity*, and *moral responsibility*). While cultural services do in general have a range of value types, service 07 (aesthetic benefits) is always given the instrumental *pleasure* value type, along with frequent reference to *knowledge*, and the relational *eudaimonic* and *individual identity* values. Lastly, spiritual and religious meaning that can be drawn from a place (09) always elicits values connected to *group identity*, along with frequent mentions of instrumental *knowledge*.

4.4 People and Values

A further layer of variables that helps explain why different types of values, and different patterns in those values can be observed in interviews about ecosystem services, are connected to the people interviewed. Just as every site is different, so is every interviewee, although most interviewees have some common attributes. Not least, in this data set, that they are employed in connection to the research sites. Although the results are not robust, there are some indications that responses about values are dependent on people's jobs, experience, gender and age. This is not a question of whether people are right or wrong in their answers but whether people perceive places and their dependencies on them very differently. Bearing in mind that this group of interviewees is restricted, and is not a broad sample of all people who depend on the sites, I would expect that the variety of responses observed here to be much greater with a more representative sample.

Although I looked at discrete variables, the interactions between the various aspects of people' characters are also likely to be important in determining the kinds of values that people express about places. Age, occupation, and education level are clearly correlated and in some cases gender will also be a predictor for education level and occupation. Similarly, I would expect the responses of someone who has visited the site to be different from those of people who have not.

4.5 Multiple Values

One final point for discussion concerns the values themselves and the risks of creating false dichotomies or hierarchies of value types. Instrumental values are the most frequently mentioned values, an unsurprising result in itself, particularly as I coded *knowledge* in this group. However, instrumental values are also most likely to be found alongside other value types, both with other instrumental values and, in particular, with relational values. This is important because it underlines again that discrete services do not carry discrete values, and that having a specific use for aspects of the ecosystem does not exclude other values for that same benefit. In fact, the richness of the ecosystem service paradigm might well be that it allows us to properly acknowledge the diversity and nuances of peoples' relationships with place, as has been more thoroughly explored in, for example, Klain's work (Klain et al., 2014). More specifically, many of those multiple values are held for cultural services. This section does not exclusively attract relational values but is dependent on having tangible elements of the system that allow the development of cultural services. I have defined the use of the system for the development of *knowledge* as an instrumental value, although of course people have different motivations to gather and use knowledge. It makes sense, then, that it sits alongside those other values. Similarly, use of features of the ecosystem for *pleasure*, another instrumental value, facilitates other emotions and motivations in people, which are expressed through the other types of value coded with it. In essence, one value is dependent on another.

Ultimately, arguments about which values to use are somewhat null and even when we think we only have an instrumental value, there are in fact layers of other values in here. Taking timber as an example, we know that it has a direct use, can be measured (m^3), valued and bought and sold. However, each of the actions and transactions involved in planting trees (Gill, 2011) , maintaining tree health, selling forest stands, harvesting timber, processing timber, producing commodities, burning waste material, disposing of used products – consists of relationships of people to place, people to goods, and people to each other (Tsing, 2015). The assumption that instrumental values are related only to measurable use (for example, money) is ultimately naïve, since use and exchange are a crude way to measure the worth of something and our relationships to it. These can never capture the multitude of overlapping and contradictory values that each individual is capable of holding for that item, activity or place (Schumacher, 1973).

Conclusion

This work feeds into suggestions from various authors that research should better recognise and integrate insights from different knowledge types, using the ecosystem services paradigm to facilitate transformative processes in society that help to improve human-nature relationships (Abson et al., 2014; Schröter et al., 2014; Berbés-Blázquez et al., 2016; Díaz et al., 2018). In our case, this is specifically to better represent the worth of the natural environments that are intertwined in people's lives – where they live, where they work and through which they understand themselves and wider society (Yung et al., 2003).

We cannot ignore or try to remove instrumental values from people's relationships with the environments that they value (or indeed from any other relationships). Instrumental values are normative, and while some may be uncomfortable with the idea of monetary values, the reality of life for most people is based within a system where access to financial resources dictates their own quality of life. Human societies have exchanged goods and services for millennia, using barter systems and then developing monetary systems, with items being exchanged that are derived from nature. Ignoring the importance of instrumental values in managing ecosystems does a disservice to this history and currently to those people charged with protecting them. They have finite budgets, are required to find self-financing mechanisms (e.g. tourist visits) and are continually threatened with budget cuts and land sell-off. It also risks devaluing the very real issues of poverty and social deprivation of the people who extract instrumental (monetary) value from these systems. We might be able to attribute traditional importance to poaching (hunting) but there are very real problems with subsistence and access to food for people who risk prosecution when doing this. We also undermine the efforts of the staff tasked to physically protect these areas if we ignore monetary value and consequently the risks that people are willing to take in order to extract that value. Frontline rangers face risks, including death, when protecting places from people who would wish to make monetary gains from felling illegal timber, trading endangered species and hunting in restricted areas. That individuals continue to engage in work that is dangerous, poorly remunerated, and often in conflict with societal norms should alert us to the need to understand their motivations for their work. These are far better captured in relational values rather than in any instrumental rewards they receive for doing this work. Relational values are how we leverage instrumental values, which this work clearly demonstrates, since instrumental values are most often aligned with other values.

At a fundamental level, when people's values are challenged, they will become defensive and entrenched in their position. Seeking to directly challenge values is a road to nowhere but one that is frequently encountered if values are not well-understood. However, people's perceptions can change, through understanding, communication and listening in ways that are non-threatening. Further, understanding and acknowledging that people have a right to different values enables better decision making, even if it is only to understand why there is conflict, or where conflict might occur. For example, changing hunting rights in a Protected

Area will directly challenge peoples' values in terms of individual and social identities. Acknowledging this, offering recognition (compensation, alternatives, less restrictive access rights, for example) without seeking to change those values may mitigate potential conflicts. It also gives a voice to people who feel they are listened to. Should add, these more challenging issues don't really surface here because of the people I interviewed.

Finally, responses in this data set come predominantly from scientists and land managers, people who might be considered to have largely disconnected and rational relationships with the areas where they conduct research. What is interesting is that even when questions about ecosystem services appear to elicit responses that indicate the instrumental values of nature, much more nuanced answers are given. The complex relationships that individuals have with natural systems are, like cultural services, everywhere. This project attempts to place them somewhere in the discourse.

Chapter 4

Connected to Place: Climate Change at Global and Local Scales

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Background

This chapter is one of a series of essays produced as part of a climate change project that was conceptualised and curated by Dr. Juanita Schlaepfer-Miller in the summer of 2016: *Klimagarten 2085*. Dr. Schlaepfer-Miller erected two greenhouses in the old botanical garden in Zürich, with common Swiss plants such as clover, maize, wheat and rye grass. One greenhouse was kept at normal temperatures (IPCC A2 business as usual scenario) and the other at an elevated temperature (IPCC RCP3PD, best case scenario). As well as the installation being fully open to the public, a number of public outreach activities were undertaken throughout the installation, to showcase Swiss research on climate change and how to plan for change. Public talks from climate change researchers were given throughout the installation, including my own talk about my research. After the conclusion of the installation and public activities, Dr. Schlaepfer-Miller asked for contributions to a handbook about the public experiment: *Climate Garden 2085: Handbook for a Public Experiment*, (Schlaepfer-Miller and Dahinden, 2017). I based my contribution, this chapter, on the talk I gave for the public (Horgan, 2017).

Introduction

This chapter is a narrative that focuses on the different ways in which people value biological resources, how they perceive and understand global change in connection to these valued resources, and the perceived risks from and responses to global change as it affects local landscapes. It frames both the ecosystem service and global change discourses within the words of the people whose knowledge has been used to produce more quantitative assessments of perceptions about ecosystem service provision (Chapter1&2) and the values that people have (Chapter 3). The following essay responds to three questions:

- How do people value biological resources and interact with them?
- How do people perceive and understand change in resources?
- How do people adapt to these changes?

I approach these questions through the words of individuals who were interviewed as part of my wider project about ecosystem services in a number of research locations.

Global change researchers largely use empirical methods to quantify biological resources and the changes those resources and ecosystems are experiencing. Approaches can include measuring leaf area index, mapping vegetation change through remote sensing applications, quantifying resource extraction, and counting numbers of individuals, populations and communities of organisms. The data collected is used to contribute to our understanding of the state of ecosystems and how those states are changing in time and space. The ecosystem services approach seeks to do this in combination with other approaches from economics and the social sciences, including but not exclusive to willingness to pay, hedonic pricing, environmental accounting, agent-based modelling and game theory. Research communities hope to use this information to provide advice to the decision-makers (international institutions, government advisory bodies, policy makers, site managers) who are tasked with planning for and managing change.

However, this does not mean that clearly defined ecological (or economic) information is enough to directly effect change on the ground (see, for example Sagoff: https://www.youtube.com/watch?v=71hrN4ce5Qw and https://thebreakthrough.org/index.php/journal/past-issues/issue-2/the-rise-and-fall-of-ecological-economics). Other, less quantifiable, factors need to be accounted for, including understanding the relationships of actors in systems – with each other and with the system itself. While some of the methods mentioned above are able to capture less data intensive information, they all require some reduction of information and struggle with connecting to more qualitative approaches.

Individuals, communities and local environments are deeply interconnected, consciously and unconsciously. As Folke illustrates in a case study from Madagascar (Folke et al., 2016), ecosystem services are not simply a component of the biosphere, of interacting biophysical processes but a unique interplay of culture within the biosphere. They are co-created by individuals with very different perceptions of and relationships to the environment around them. For example, a researcher may see a tropical forest as a vital resource of data enabling them to understand how species compositions change over time as the climate becomes drier. The forest manager, on the other hand, may view 'their' forest as vital for providing them with a livelihood, habitat for many species, and a recreational resource for local communities. A local smallholder (perhaps also a manager or researcher) may value how the forest provides an abundance of pollinators, even if it is also a source of animals that feed on their crops. At the same time, any one of these individuals may have a long family history connected to the forest, or to the locality. The diversity of relationships individuals have with the same resource creates a cultural resource, as common events, stories and myths bind these perspectives together (Klain et al., 2014). The severe flood, the year of extreme drought, the marauding elephant become shared memories (Yung et al., 2003).

These facets of the ecosystem are not so easily captured by counting species numbers, measuring drought resistance, or through timber prices, although they may be there. As Backhaus has said:

> *"… the same landscape can be perceived in various different ways and consequently it is being regionalised in different ways too. This, however, is not always recognised in a reflected and discursive manner. Rather, many think that their own perception of landscapes and the regionalisation that is connected with this is more or less the real thing."* (Backhaus, 2011)

Recognising this is important for realising that the observed, scientific 'facts' are not the same as 'the real thing' for different actors in the system, and that if this is the case, advice based on 'facts' may not be well-received and understood. Further, marrying multiple perceptions of 'the real thing' with 'facts' may give more solid foundations to those facts. Memories of the drought can be matched to changes in tree growth, or the local significance of the Siberian crane may be related to its role in determining the seasons, as well as its increasing scarcity. I found that many scientists I interviewed about ecosystem services began to speak descriptively about their research systems. They revealed their own perceptions of the places where they work, translating their experiences into terms other than data. Setting this alongside the responses of rangers, foresters, and site managers, there is an opportunity to detect points of contact and commonality. In this sense, the experiential and emotional may align more than the numerical (Sagoff, 2013).

Awareness of this range of perceptions also helps to explain why responses, or adaptations, to change are not objectively optimal. Just as perceptions differ, so do responses. To protect crops from foraging monkeys that lack resources inside the forest, the optimal response might be to increase the available food in the forest by replanting or by extending the forest area. However, the more practical, achievable response from a smallholder is to net crops, to deter, even to eradicate the monkeys. It is unlikely that a smallholder has enough influence to advocate forest planting or expansions – if this is even something desirable from their perspective.

The ability to respond optimally depends on having both heterogeneous, resilient ecosystems and resilient social systems. A smallholder with little power to influence how the forest is managed – even to communicate the problem of marauding monkeys – probably has little power within the wider social system. Systems that are open and accessible allow information sharing, debate and compromise, enhancing the options for and ability to adapt to change, building more resilient systems, both social and ecological (UNESCO, 2003; Folke et al., 2016).

Creating these resilient systems depends on diversity, including a diversity of knowledge. However, as mentioned above, knowledge production for empirical work necessarily involves the reduction of detail to quantifiable, discrete, analysable chunks (Meinard et al., 2014), leading to an inevitable loss of other valuable information. This is unavoidable, as individually, we cannot possibly be aware of all perspectives or changes taking place around us. Consequently, one research approach cannot capture all facets of a system and the culture that has developed within it. It is therefore important to seek to combine information from multiple sources and perspectives, using multiple approaches (Norgaard, 1989; Jasanoff, 2004; Tengö et al., 2014). This is not straightforward, as Tsing points out:

> *"Telling stories of landscape is not easy and requires getting to know the inhabitants of the landscape, human and not human. This is not easy, and it makes sense to me to use all the learning practices I can think of, including our combined forms of mindfulness, myths*

and tales, livelihood practices, archives, scientific reports, and experiments." (Tsing, 2015)

Part of recognising how place, or landscape, is multifaceted, and capturing that variety, means telling and listening to stories. Personal experience provides a great deal of detailed information, and gives more complete pictures of the impacts of climate and biodiversity change on human lives and on the systems and species they depend on (Norton and Hannon, 1997; Kimmerer, 2013).

These richer expressions of experiences, offered up throughout my interviews, create a window on aspects of human perception and behaviour that can help towards protecting biocultural heritage, in recognising, in less complex terms than research papers and policy documents, the importance of human-nature relationships. This is important for policy makers, but more, it is important for researchers to enable differentiated interpretation and communication of their findings.

As such, this work is interesting as it contributes an alternative method for dealing with the information given to me by the people interviewed and may allow more of their own voices to be heard. It may also offer a different way to view the knowledge produced, possibly responding to potential criticisms of how research produces and then communicates knowledge (Jasanoff, 2004).

Methods

I conducted over one hundred interviews with a cross section of a scientific community engaged in climate and biodiversity change research, and with local site managers, rangers and research assistants. Interviewees included doctoral students, professors, foresters, rangers, ecologists, geographers, anthropologists, statisticians, and biologists. The interviewees spoke a number of mother tongues, including English, French, German, Malaysian, Russian, and Spanish. The majority of the interviews were conducted in English, but some have been translated from Chinese (or local dialect), German and Russian. Cultural differences were wide, with American, Chinese, Dutch, Italian, Malaysian, Russian, Seychellois, and Swiss nationals amongst the interviewees.

I noted most interviews as written text, and recorded and transcribed a small number. Most interviews from the Chinese site were written responses from interviewees, as the questionnaires were sent to a large number of doctoral researchers. Eight were face-to-face interviews. The Russian site, Kytalyk, had only one very short interview with the site manager, and all other interviews for this site are with researchers. The Principle Investigator has a long history with the site and the management staff. One interviewee from this site is also local.

While the interviews themselves were framed within the ecosystem services discourse, many responses went beyond this narrative and became stories of personal connection, individual concern and perspective. It is this personalisation of the multiple challenges of global change that I wish to capture here. I have therefore taken insights from the interviews to construct a narrative on the importance of biological resources to different actors, and how these resources are perceived across a latitudinal range of ecosystems. I also reflect on how interviewees see change in these systems, and how they and others are adapting to this.

The narrative is a retelling, the words are translated and transcribed but I hope some of the voices are a little clearer. Not all voices are represented, and those that are, are biased towards scientific, pragmatic and environmentally aware individuals. However, these are often the voices calling most strongly for protection of the environment and working most closely with it.

Narrative

Our relationships with our planet are intricate and multi-layered, and have been formed over millennia (Ruddiman et al., 2015). Across ecosystems, societies and cultures, people express a sense of connection with their ‘place’. How people speak about the natural world, the ways in which they interact with soil and water, plants and wildlife, all reflect these deep connections to and care for place. Climate and land-use are shifting, and changes to weather patterns, seasons, agriculture and habitats all alter human interactions with planet Earth. Whether gardening or gathering in a changing climate, connection and care are as important as technology, for humans to learn how to adapt to a changing planet (Steffen et al. 2015).

Through interviews with people working and researching in different parts of the world[1], I have been able to trace some of these connections and perceptions of change, alongside indications of a continual ability to adapt. In this essay, I would like to share stories from the Arctic Circle, the Qinghai-Tibetan plateau, Switzerland, the Seychelles and Malaysia: stories of peoples’ relation to place, and how a changing climate is already affecting the plants and animals with which they are connected.

People living beyond the Arctic Circle, around the Kytalyk Resource Reserve in Sakha Republic (Siberia), have found ways to live in an environment that is dark and frozen for at least half of the year (Beltrán and Phillips 2000). While they can now receive goods from around the world, connections with the land and its resources remain. They collect mushrooms and berries for subsistence and because they are culturally important – making jam to give to relatives and visitors is part of their social relations - *“they know the sites to go for them. They send jam to relatives”* (kes_01). Reindeer (*Rangifer tarandus*) herding is also still integral to peoples’ lives, and despite dramatic changes in how this is practiced, people and communities working with reindeer continue to *“use everything from reindeer – they eat all parts of them. Make clothes. Even eyes…there are…2 types - domesticated and wild. Domesticated are bred by local people and kept by Obshchinas[2]. They're moved from place to place by the Herders”* (kes_01). Communities are also very dependent on fish as a food source, with fishing a regular and important activity. People commute to fishing villages in the summer and stay there until the winter. As one person said, *“Fish, I think are very important. Fish is life”* (kes_04), showing the role of the rivers on which they depend

[1] Sakha Republic, Russia, Kytalyk Resource Reserve; Haibei Province, China, Qinghai-Tibetan Plateau; Switzerland, Laegern Forest; Seychelles, Aldabra Atoll; Malaysia, Pasoh Forest Reserve (Peninsular), Danum Valley Conservation Area (Sabah), Lambir Hills National Park (Sarawak)

[2] Communes

for food, driftwood, transport and winter roads - *"everything comes from the river… Local people couldn't do without it. They commute to fishing villages in summer and stay there all the time"* (kes_02). A deeper sense of place is reflected in the symbolic importance of the Siberian crane (*Leucogeranus leucogeranus*), or *kytalyk*. The Resource Reserve was established by local people to protect this species, and one person described the area as a "*reservoir of traditional practices*", centred on the Siberian crane. Another mentioned the traditional dances based on the crane's mating dance, describing this as "*a powerful symbol*" (kes_02), derived from a "*spiritual bird*" (kes_06).

Similar kinds of connection are also apparent on the alpine grasslands of the Qinghai-Tibetan Plateau in China (Zhao and Zhou 1999). Here people continue to collect wild mushrooms and plants for food and medicinal use, they *"collect some kinds of mushroom for food"* (hes_30), and use *"wild plants… for stuff of Chinese medicine"* (hes_10). This includes the caterpillar fungus (*Cordyceps sinensis*), silverweed (*Potentilla anserina*), and gentian (*Gentiana spp.*) - "*they usually collect mushrooms and Cordyceps sinensis in the grass. They eat mushrooms and sell cordyceps sinensis*" (hes_04). Residents of the plateau depend directly on this grassland habitat; as one interviewee said, *"residents' lives rely on the grassland"* (hes_16), using *"yak fur, sheep fur to make quilts"* (hes_16), "*It sustains the living*" (hes_07). People herd yaks (*Bos grunniens*) and Tibetan sheep, and harvest crops such as highland barley (*Hordeum vulgare var. coeleste*) and oats (*Avena sativa*). The use of natural resources extends to "*soil ... used to make bricks*" (hes_37) and "*dried cow dung and sheep dung for burning and warming*" (hes_37). The connections are reflected in the cultural importance of yaks and the caterpillar fungus, both are "*the symbol of Qinghai*" (hes_14).

It is not only across these vast, wild landscapes that elements of traditional practices are maintained. In and around the temperate forests of Switzerland, people continue to collect wild plants for food, such as wild garlic (*Allium ursinum*), berries and mushrooms - "*there's wild garlic that people pick at some point during the year then it gets toxic. I'm sure there are some plants as well, maybe in the spring*" (les_06). In Canton Aargau, mushroom collection is regulated by the *Pilzkontrolle* office, suggesting the continuing importance of this activity. While it, too, is strictly regulated, hunting of wild animals including deer (*Capreolus capreolus*) and boar (*Sus scrofa*) is an important activity, both for food and for pest control. This is connected with the agriculture around the forest, where farmers harvest a variety of crops. As one person said, "*around the forest area. It's important for small villages*" (les_01). The forest, growing on a distinctive limestone ridge, the last outcrop of the Jura mountain chain, is also a well-known hiking area, making it *"important for recreation and the local economy"* (les_04), and also *"for the biodiversity, for the landscape and for the people"* (les_06) (Balvanera et al. 2006).

The importance of biodiversity to people's lives is echoed far out in the Indian Ocean. The raised coral atoll of Aldabra (Beamish 1970), 400 km from the main Seychelles Islands has many endemic species. Before 1982, when the atoll became a World Heritage Site, the Aldabra giant tortoise (*Aldabrachelys gigantea*), green turtle (*Chelonia mydas*), flightless Aldabra rails (*Dryolimnas aldabranus*), and ibis (*Threskiornis aethiopicus abbotti*), as well as bird's eggs, were harvested: "*in the early days (pre 1982) lots was grown and they harvested tortoise and turtle, rails, ibis, eggs*" (aes_13). Now, imbued with their own "*stories and folklore*" (aes_04), the Aldabra giant tortoise and Aldabra rail have become "*national emblems*" (aes_04), displayed on coins and stamps. For the small group of people who live in the research community on the atoll, the abundant fish are essential "*for subsistence*" (aes_03). However, fishing is more important than simply providing protein. One interviewee described how necessary it is to "*reduce boredom, therefore it's recreationally important*" (aes_03). And the name of the atoll probably connects to a time when islands were important navigational aids to early Arabian explorers. One interviewee suggested "*Aldabra*" was derived from *alhadra*, the Arabic for *green*, because "*There's a green reflection on the clouds from the lagoon. Maybe it's Alhadra – a green star for navigation*" (aes_14).

Tropical forests also sustain many peoples and cultures (Buschbacher 1990, Edwards et al. 2014). In and around the tropical forests of Malaysia, local people continue to collect plants and fruit to eat, including *petai* bitter bean (*Parkia speciosa*), *keledang* (*Artocarpus lancefolius*), *ulam* salad (*Centella asiatica*), and *kerdas* (*Archidendron bubalinum*). They also collect fungi, using the traditional local knowledge that is essential for people to know "w*hich are the poisonous ones*" (pes_07). Shifting agricultural production continues around the edges of the forests, with smallholders cultivating "*paddy rice, oil palm, chickens, pig, fruit vegetables, fish*" (lhes_05) and still hunt *"on the border, wild boar - in oil plantation*" (pes_05). Pigs may be food and monkeys may be pests, but the connections to the forest and its inhabitants run deeper than this. The white-handed gibbon (*Hylobates lar*), "*rhino, elephant - these are symbolic*" (des_03) in Malaysia. While communities and farming practices may have altered how people use the forests – especially as they are often reserves - indigenous people still "*use forest for everything…(they have a) close relationship*" (pes_05) with it. Some interviewees made careful references to "*Tebu places… - this means you must respect the forest*" lhes_03. For some, there are other reasons why forests are important: "*people escape here to feel better (pes_03)*, "*Without the forest we would be living with no meaning"* (pes_07).

These close relationships with land, with wildlife, and within ecosystems mean that people notice changes. In Kytalyk, people have noticed changes to reindeer migration patterns; they say "*they don't see so many wild reindeer coming through as they changed the migration route. They don't really know the reason*" (kes_06). This is echoed in comments from the Qinghai-Tibetan Plateau, where people suggest that "*unique natural scene(s) seem to be fewer and fewer and we should preserve it naturally*" (hes_10). In a temperate Swiss forest, long-term residents have seen seasonal patterns shift, "*there are changes in the management systems, so there is a question of how is the forest managed*" (les_01). On Aldabra, the food people eat has changed, as tortoises and turtles are protected, and interviewees notice the direct impacts of climate change: "*beach erosion is a natural process - some sand doesn't come back. We lost the old cemetery*" (aes_04). Changes to wildlife in Malaysian forests also don't go unnoticed. Logging has in the past led to the loss of big trees, they "*used to have big trees but now they're all very small*" (pes_07), while the "*bird population seems to have declined*" (pes_05), and only small mammals are present: there are "*no big mammals, some but quite small. Maybe in the 80s there were leopards but less than five*" (pes_05) (Harrison et al. 2013). It isn't just the wildlife that has changed, with one interviewee describing increased flooding in his village. Human movement is impacted by environmental and socio-economic change: for example, indigenous territories become state owned, government land becomes privately owned, and small-scale subsistence farming is swallowed up by large oil palm plantations (Ichikawa 2006). As a result, people move, looking for new opportunities in different sectors. This change is illustrated by comments from Malaysian Borneo about the indigenous Orang Sunai who no longer subsist inside the forest "*but live around the edges and around Sabah*" (des_07). They now have more settled, agricultural and mixed livelihoods.

Some of these changes may be part of quite natural processes, as societies and communities shift to more stable lifestyles that are less dependent on their surrounding environments. However, some changes are worrying, bringing threats to health, to livelihoods, and to ecosystems themselves (Lal 2009). Changes to the tundra system around Kytalyk affect indigenous people and traditional ways of life, it "*has a very bad impact on livelihoods if it changes*" (kes_06), where many people remain dependent in some way on the system. These changes range from altered reindeer migration patterns, through earlier and less predictable snow melt destroying winter roads, to changes in fish stocks in rivers. The changes are system wide; as one interviewee said, global warming is "*unstoppable there*", for as the soil warms it releases CO_2, and although this is invisible, "*it has a huge impact for the world*" (kes_04) (Post et al. 2009, Kintisch 2015). There are concerns also about social changes, with younger generations disconnecting from their traditions - "*children didn't know what the reindeer look like…as there are reduced numbers*" (kes_06) – and migrating to the towns for better employment opportunities (Xanthaki 2004).

The grasslands of the Qinghai-Tibetan Plateau are also "*sensitive to global change and threatened by anthropogenic activities*" (hes_14). Interviewees expressed concern about the potential CO_2 release from this area with climate warming. Others perceive that, once it is damaged, it is very difficult to restore such a unique landscape. The biggest harm noticed in our Swiss forests is the increasing prevalence of ticks carrying both Lyme disease and encephalitis: there are "*more ticks so it's spreading Lyme's Disease*" (les_04) (Rieille et al. 2014).

On Aldabra the threats are varied, with the boundary between the land and the sea constantly shifting. "*Coastal erosion means it is always moving back and forth. Climate change and sea level rise make this worse*" (aes_07). The plants and animals introduced for production, to feed the early workers, and by accident, have been a significant threat to such a sensitive ecosystem. These include rats, goats, cats, invasive birds, nineteen plant species and one species of gecko (Harper and Bunbury 2015).

While not as exposed as a coral atoll, tropical forests are also perceived as subject to definite threats. Interviewees often note the lack of animals due to deforestation: "*don't see animals so much because of deforestation*" (lhes_05), and the negative changes in air temperature and humidity outside the forest: "*it's cooler to walk in the forest - very hot in oil palm - not healthy*" (lhes_05). Increased erosion and muddy rivers are seen to be a consequence of the spread of oil palm plantations: "*upstream there is oil palm and a previously logged site and sometimes the river floods from this but it gets cleaned through the valley*" (des_08). People were often very clear that the forest is necessary to maintain a clean, functioning system: "*without forest there would be a lot of mud in the river. In the rainy season it is very muddy. When trees fall down the river is more muddy*" (des_07). They recognise that the forest is "*a natural ecosystem but if this gets disturbed these services are also disturbed*" (des_01) (Struebig et al. 2015).

This seems to paint a very negative picture of a changing world; but people, communities and ecosystems are adaptable. Our dependencies change, building on past knowledge while adopting new technologies, practices and traditions. For example, while people in Siberia still collect berries and mushrooms, these are now "*important but probably not for sustenance*". However, collecting berries remains a seasonal tradition. People also combine the old and the new, building fishing huts from "*peat and turf over chicken wire. Maybe cotton, not sure if they use that*" (kes_02) and continue to use "*Reindeer skins for insulation*" (kes_02) where they can. Traditional knowledge is preserved, with reindeer herders organising annual events to teach people in the villages their traditions "*people from the camps go to the villages to teach traditions*" (kes_06). In China, old and new uses are found for natural resources. Pikas (*Ochotona dauurica*), marmots (*Marmota bobak*) and false zokhor (*Myospalax aspalax*) are collected for pest control and food, but also for scientific research "*they collect and hunt pikas, marmots and eagles. To eat, make animal specimens, to sell and do science research*" (hes_14). In fact, the current importance of the area for research is in part what is helping to preserve it: "*This area is great place for scientific research especially for global change and no any pollution, and it should be preserved*" (hes_37).

Some adaptations are in response to very recent changes, such as the noise pollution from airports and motorways. Laegern forest can be "*extremely important… when you are in it. You can't see or hear the road*" (les_05). This adaptability extends to dealing with other human-caused problems. On Aldabra, many of the invasive species have now been eradicated: "*used to have feral goats for food – they were eradicated in 2012. The browse line is now tortoise height*" (aes_02). They also "*used to grow sisal but now eradicated because it was invasive*" (aes_13) and people are "*very careful about which seeds are brought in*" (aes_01). While fish are important for the small community there, they have learned to harvest carefully without disturbing the system or creating by-catch "*they had been overfishing and produced waste, therefore they now reduce waste and spread fished areas*" (aes_02). As one person said, people recognize that "*in the past human beings were reckless, careless" (aes_04)* (Stoddart 1971), but now Aldabra is "*a success story*" (aes_06) (Gaymer 1966). Sometimes it isn't possible to avoid land use change; often we need agricultural land rather than forest. People interviewed in Malaysia find value in both, seeing that having oil palm and forest next to each other can be beneficial: "*you see more wild animals in oil palm near forest than you see in the forest because they come out for food – it's hard for them between seeding times. It's a good symbiosis. You don't see many animals in oil palm away from forest (I was lucky when this was made a National Park, it's good for my crops)*" lhes_03. The adaptability of other species is noticed in other ways, for example the monitor lizard (*Varanus salvator*) that "*tidies up scraps after tourists – you always see them at Latak Waterfall*" lhes_04. Finally, global change – whether this is change to the climate or change in how land is used – has also brought a greater awareness of the bigger picture, enhancing the importance of one's own place: "*Every place is a piece of the bigger jigsaw puzzle, it all does something. It's really important to contribute to your piece of the puzzle. You know you can have sand from the*

Sahara desert on the roof of the car and you realize it's not so far away" (noticed by a forester in the Laegern forest).

Above all, these stories have shown how our relationships with wildlife, with gathering, with keeping our hands in the soil, are constantly being renewed. Many people see themselves as guardians of wildlife and the ecosystem, valuing what has now become rare. As wildlife becomes scarcer, it becomes more mystical, preserved in traditions such as the crane dance, giving a reason for the creation of reserves to protect it, and still providing spaces for traditional knowledge to be experienced. We will always be dependent on the Earth for our own sustenance, and we must be able to develop a deep relationship with her. Preserving spaces also protects our connections and traditions, and helps us to understand that in a changing world our gardens can grow if we listen to and care for them: "*It's special but it isn't unique. The forest grew into my heart*" (Laegern Forester).

General Discussion

Overview

In this thesis, I determined the ecosystem services that researchers and site managers perceive to be present and important at diverse research locations, and identified areas of uncertainty and disagreement. I further investigated the variety and range of values that those experts have for those locations, in relation to ecosystem services. To draw together the stories of those sites through the perspectives of the interviewees, I also built a narrative around how people relate to place and continue to adapt to environmental change. I have been able to provide important insights into how perception studies could be used to establish baselines of ecosystem services, and have identified aspects of ecosystem services that people are either uncertain, or disagree about. I have also shed light on the ways in which values inform peoples' relationships to the places they depend on.

Main findings

In Chapter 1, I showed that interviews with experts from research and management can reveal the ecosystem services that are most likely to be provided by a specific location. While this approach does not determine quantitiesof services, it is helpful in establishing which services people perceive to be important, something, that cannot be assessed by analysis of biophysical data only. Consequently these are the services – or components of the system – that might be most relevant for further assessment. I was able to demonstrate that each location has unique suites of ecosystem services, including bundles of services that are positively correlated in peoples' perceptions. While I found a general pattern of perceived negative relationships (trade-offs) between cultural and provisioning services, which is in keeping with other empirical studies (World Resources Institute, 2005a; Cavender-Bares et al., 2015), using a network analysis approach, I also uncovered positive relationships with provisioning services that may not be apparent from more traditional approaches. I additionally showed that these patterns of correlations were different for each research site, reinforcing the necessity of taking local context into account in ecosystem service assessments (Fisher et al., 2009). I also demonstrated that it is possible to use perceptions of experts, from a relatively low number of interviews, to indicate which ecosystem services are delivered at specified locations. These baselines may not be definitive but are important for establishing the services on which to focus greater research effort, for example.

By exploring uncertainty in peoples' perceptions of ecosystem services in Chapter 2, I was able to show where concepts and information are least clear, and where it might be most profitable to focus future ecosystem service research effort.

It was clear that even experts are uncertain and may disagree about the specific role that ecosystems play in providing, in particular, the regulating services that are essential, not only for human life, but for all life on earth. Experts had clear ideas about ecosystem functions, but transitioning from this to the direct contributions these functions make to human welfare appears to remain an area that demands better research enquiry and integration (Daw et al., 2011; Howe et al., 2014). In exploring the known attributes of the people I interviewed, I could also cautiously identify some patterns in how individuals revealed uncertainty. Most importantly, I found that people who identify themselves as local, regardless of other attributes, have clearer perceptions about ecosystem service provision at local scales. This is an important addition to on-going work that seeks to validate and integrate different knowledge types into the ecosystem services, and social-ecological systems fields (Tengö et al., 2014, 2017).

In Chapter 3, I assessed the different value types assigned to ecosystem services, which has rarely been performed before. I was able to demonstrate that the value types selected in this study, can be broadly aligned with the three ecosystem service sections: instrumental with provisioning services, intrinsic with regulating services, and relational with cultural services. However, this alignment is not clear-cut, with cultural services eliciting both the highest abundance and diversity of values from interviewees. I also show that, despite having more relational values assigned to them than either provisioning or regulating services, in fact cultural services elicit more instrumental than intrinsic or relational values. This indicates a strong connection between culture, tangible elements of ecosystems, and the relationships that people have with them. These connections are reinforced by number of people who held both relational and instrumental values for some cultural services.

One important aspect of this study is how frequently knowledge, as an instrumental value, occurred. Given that many of the interviewees are engaged in research that depends on knowledge generation, this reflects the role that research plays in these locations. It echoes the views that some site officers voiced to me about the importance of having high profile, international research taking place in Protected Areas, as it supports and legitimises that protected status.

I uncovered the multi-layered, diverse values that individuals hold for place, framed within the context of ecosystem services. This that assigning one type of value to one aspect of the system is inadequate for fully capturing people's relationships with and dependencies on nature (Daw et al., 2011; Chan et al., 2012a). Excluding cultural services from ecosystem service assessments risks omitting the multiple values that are attached to tangible and intangible elements of place. Equally, seeking to negate the importance of instrumental values risks ignoring the reality of people's interactions with nature.

In Chapter 4 I had the opportunity to bring together the many perspectives that interviewees have about ecosystem services and the research sites, and the stories they told about them. I was able to frame these within a wider narrative about global change, and demonstrate how it is possible to move between empirical methods and more conceptual approaches, allowing, to an extent, the participants in the research to speak for themselves.

Areas that worked well

I explored a number of aspects of perceptions related to ecosystem services and invested significant effort in order to access the interviewees, within the research and site management communities. This endeavour was extremely informative for the cross-departmental, interdisciplinary research programme, URPP GCB, to develop an understanding of the network of relationships that are necessary for knowledge generation, sharing, and integration across diverse groups. Additionally, although the process was time consuming, the approach I took to try to integrate every research site was instrumental in building an appreciation of the importance of fostering and maintaining good communication with all stakeholders in the research programme.

The role of good communication is well-illustrated by the outputs in particular from Chapter 3, where my approach was explorative and thereby yielded in-depth information on values. While I could now make refinements to the study, the power of focused text analysis that I uncovered is probably under-appreciated in more empirical, place-based research. In particular because, in our case, the main research thrust is towards more quantitative biophysical approaches used in natural sciences and remote sensing.

Finally, while the data itself is quite unbalanced, with uneven numbers of interviewees at each site, I was still able to show that a relatively low number of interviews can yield asymptotic results. This is extremely encouraging for inspiring greater inclusion of perception data alongside biophysical empirical methods in ecosystem services research.

Areas for improvement

A number of improvements could be made to my study, including developing, within the constraints of the research locations, a more balanced design. Equal numbers of interviews, rigorous attention to conducting all interviews under the same conditions, and a more even distribution of the various interviewee attributes would make the data easier to work with and the outputs would be more robust.

I would also suggest that using either maps or images as boundary objects in order to focus discussion and have better co-production of knowledge might give clearer results, particularly when discussing regulating services. This was an approach that I considered, however, careful attention should be paid to site context in relation to the maps and images that are used. It would be important to have sufficient knowledge about each site, and about the specific services that should be focused on, to make informed choices about which images would be most appropriate. However, this could be a fruitful avenue of enquiry in future work.

I could also have combined the semi-structured interviews with a structured questionnaire, administered either online or through the post. However, this approach is constrained by access issues. For a number of the sites, an online option is not viable, while sending forms through the post is costly, time consuming, and difficult to implement properly in locations that are less accessible.

Expanding the group of interviewees

It is particularly interesting to find that without direct prompts, a subset of people so readily revealed multiple values for the places where they live and work. This suggests a huge potential in uncovering a greater range of values with a more representative group of people.

Ideally, for a more inclusive sample of perceptions, this study would be expanded to a more diverse group of people. To do this, we would need to set up research agreements for each site, since interviews with people who are not directly involved with the research site is not necessarily permitted. We would also need enough information, some of which is provided by the current study, to determine the individuals we should interview. This includes considering power relations, cultural appropriateness, and language barriers, for example. It might be most desirable to constrain an expanded study to one research site and have a locally based researcher carry it out.

Next steps

Following the above points, there are some clear potential future actions that could be taken to expand on this study. The first of these is, as I suggest above, to carry out more detailed interviews with a wider group of people at each location. This does not need to happen at every site necessarily and is dependent on policy, management and research relevance. The use of images and/or maps would potentially add detail to a further study.

I would also suggest that uncovering and detailing the uncertainties around regulating services would be extremely helpful. This continues to be an area where our understanding of ecosystem functioning struggles to conceptually connect with ideas about human well-being. Clarifying them in detail, in a site and context specific framing, might help to bridge the gap between ecosystem functions, regulating services and human dependencies.

It would also be beneficial to combine these approaches with biodiversity data, to explore whether people perceive more services at sites with more biodiversity, or perceive specific connections between biodiversity and particular ecosystem services. Interviewees in our data referenced species in relation to some services, some of which were their study species, and also mentioned components of ecosystems that were important for some services. While I did not explore references to biodiversity in this study, it would potentially help to fill some of the gap in our understanding of the detail about human dependencies on biodiversity.

Integrating any future ecosystem services work in this programme with the policy and management requirements of the sites themselves would be increase the relevance of the outputs. This study has taken a rather more theoretical approach but is sufficient to provide a baseline from which to carry out more engaged ecosystem service assessments.

Implications for the ecosystem services concept

This research comes at a time when IPBES finds itself exploring how to meet the challenge of integrating indigenous and local knowledge (ILK) in its assessments, how to conduct assessment on values, and when the ecosystem services research community is debating its terminology.

With regard to different knowledge dommains, it is important to recognise that local knowledge comes in many forms, from a large and disparate community of people in any one location. Think, for example, of the number and range of local people around lake Zurich. What is important here is to understand that anybody can be local. A large number of the researchers who were interviewed were local to the research sites, and I found that being local appears to influence how certain people are in their perceptions of their home environment. Whether those perceptions are 'right' or 'wrong' is less important to the ecosystem services concept than recognizing that local people have very clear perceptions of and relationships with the places where they live. Such local knowledge cannot be ignored if there is a need for policy and management decisions to be based on ecosystem service assessments that are seen as legitimate and acceptable to local communities

(Berbés-Blázquez, 2012; Posner et al., 2016). This demonstrates that the ecosystems services concept has some way to go in fully engaging with and defining what is meant by local knowledge.

With regard to values, this study suggests that to have a good understanding of these, ecosystem service assessments must take an inclusive and open approach to cultural services. Values are where it is possible to find commonalities and conflicts between actors (Primmer et al., 2018), and as this study illustrates, there are more, and more diverse values expressed for cultural ecosystem services. Integrating approaches that include multiple values, as well as the number of plant species in a wild flower meadow, might for example help to provide more nuanced assessments that assist in making management decisions that are acceptable and those that might engender conflict.

This study also gives weight to the assertion that policy is not based purely on economic factors (Primmer et al., 2018), despite this being a common criticism of the ecosystem services paradigm. Of course, management decisions are indeed made on the basis of the available budget at any site, and there is no doubt that money is the 'bottom line', however this misrepresents the motivations of the people responsible for making those decisions. I did interview people who were primarily responsible for managing site budgets, and arguably the high number of instrumental values expressed could be understood to represent, abstractly, monetary value. However, I did not need to create an instrumental values code for 'financial' value, as this simply wasn't mentioned enough, if at all. From the point of view of the ecosystem services concept, this illustrates strongly that although money may be one mechanism through which value is expressed, it is very far from representing the values that motivate land managers, decision makers, and researchers to protect, conserve and sustainably manage the places they are connected to.

The value of the thesis as a whole

While each chapter of this study stands alone, taken together they help to form a much more detailed picture of perceptions of ecosystem service provision. The suites and bundles of services from Chapter 1 are not definitive, so it is important to have the exploration of both uncertainty and disagreement in Chapter 2, to emphasise that ecosystem services cannot necessarily be perceived with absolute certainty or agreement. This invites caution when considering how to present ecosystem service assessments to different audiences. If people fail to recognise some services, or how they are dependent on them, or if they simply disagree with aspects of the assessment, then it becomes less credible and legitimate to those audiences. Ecosystem services are fundamentally about people, and in this sense it is unrealistic to expect physical or biological quantities to map directly onto people's perceptions (Carnol et al., 2014). However, to better understand what might motivate people to perceive or recognise ecosystem services, and more importantly, to anticipate tensions (Primmer et al., 2017), we need the type of information that is provided by Chapter 3. This gives more space for the diverging ontological and epistemological perspectives of different actors, even within a restricted sample of interviewees. While the framing of the chapter remains ecosystem services and has a specific set of definitions of value, there is sufficient breath in the values to demonstrate that individuals have different values for ecosystems. Importantly, this can also facilitate the identification of commonalities between people. Chapter 3 also helps uncover why some cultural and provisioning services are positively correlated in Chapter 1 by adding detail about the values people attach to them. If relational values, such as social cohesion or group identity, are associated with gathering wild food, for example, these values indicate that there are cultural services delivered by this activity (e.g. heritage or recreational benefits). Revealing the multiple values connected to ecosystem services therefore helps to explain why I find that cultural services are everywhere. Adding the narrative of Chapter 4 places the study in its many site-based contexts and adds a more human dimension to the data, recognising that it is drawn from the thoughts and feelings of real people.

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Appendices

Appendix 1 CICES, General Introduction
Appendix 2 Research Questionnaire Examples, Chapter 1
Appendix 3 Site Visit Protocol, Chapter 1
Appendix 4 Ecosystem services included in analyses, Chapter 2
Appendix 5 Services showing some effect of explanatory variables, Chapter 2
Appendix 6 Supplementary Data for Chapter 3

Appendix 1: CICES V4.3: Provisioning Services

CICES for ecosystem service mapping and assessment					Note: this section is not complete and for illustrative purposes only. Key components could change by region or ecosystem.
CICES for ecosystem accounting				Note this section is open in that many class types can potentially be recognised and	
Section	**Division**	**Group**	**Class**	**Class type**	**Examples**
This column lists the three main categories of ecosystem services	***This column divides section categories into main types of output or process.***	***The group level splits division categories by biological, physical or cultural type or process.***	***The class level provides a further sub-division of group categories into biological or material outputs and bio-physical and cultural processes that can be linked back to concrete identifiable service sources.***	***Class types break the class categories into further individual entities and suggest ways of measuring the associated ecosystem service output.***	
Provisioning	Nutrition	Biomass	Cultivated crops	*Crops by amount, type*	Cereals (e.g. wheat, rye, barely), vegetables, fruits etc.
			Reared animals and their outputs	*Animals, products by amount, type*	Meat, dairy products (milk, cheese, yoghurt), honey etc.
			Wild plants, algae and their outputs	*Plants, algae by amount, type*	Wild berries, fruits, mushrooms, water cress, salicornia (saltwort or samphire); seaweed (e.g. Palmaria palmata = dulse, dillisk) for food
			Wild animals and their outputs	*Animals by amount, type*	Game, freshwater fish (trout, eel etc.), marine fish (plaice, sea bass etc.) and shellfish (i.e. crustaceans, molluscs), as well as equinoderms or honey harvested from wild populations; Includes commercial and subsistence fishing and hunting for food
			Plants and algae from in-situ aquaculture	*Plants, algae by amount, type*	In situ seaweed farming
			Animals from in-situ aquaculture	*Animals by amount, type*	In-situ farming of freshwater (e.g. trout) and marine fish (e.g. salmon, tuna) also in floating cages; shellfish aquaculture (e.g. oysters or crustaceans) in e.g. poles
		Water	Surface water for drinking	*By amount, type*	Collected precipitation, abstracted surface water from rivers, lakes and other open water bodies for drinking
			Ground water for drinking		Freshwater abstracted from (non-fossil) groundwater layers or via ground water desalination for drinking
	Materials	Biomass	Fibres and other materials from plants, algae and animals for direct use or processing	*Material by amount, type, use, media (land, soil, freshwater, marine)*	Fibres, wood, timber, flowers, skin, bones, sponges and other products, which are not further processed; material for production e.g. industrial products such as cellulose for paper, cotton for clothes, packaging material; chemicals extracted or synthesised from algae, plants and animals such as turpentine, rubber, flax, oil, wax, resin, soap (from bones), natural remedies and medicines (e.g. chondritin from sharks), dyes and colours, ambergris (from sperm whales used in perfumes); Includes consumptive ornamental uses.
			Materials from plants, algae and animals for agricultural use		Plant, algae and animal material (e.g. grass) for fodder and fertilizer in agriculture and aquaculture;
			Genetic materials from all biota		Genetic material (DNA) from wild plants, algae and animals for biochemical industrial and pharmaceutical processes e.g. medicines, fermentation, detoxification; bio-prospecting activities e.g. wild species used in breeding programmes etc.
		Water	Surface water for non-drinking purposes	*By amount, type and use*	Collected precipitation, abstracted surface water from rivers, lakes and other open water bodies for domestic use (washing, cleaning and other non-drinking use), irrigation, livestock consumption, industrial use (consumption and cooling) etc.
			Ground water for non-drinking purposes		Freshwater abstracted from (non-fossil) groundwater layers or via ground water desalination for domestic use (washing, cleaning and other non-drinking use), irrigation, livestock consumption, industrial use (consumption and cooling) etc.
	Energy	Biomass-based energy sources	Plant-based resources	*By amount, type, source*	Wood fuel, straw, energy plants, crops and algae for burning and energy production
			Animal-based resources		Dung, fat, oils, cadavers from land, water and marine animals for burning and energy production
		Mechanical energy	Animal-based energy	*By amount, type, source*	Physical labour provided by animals (horses, elephants etc.)

Regulating Services

Regulation & Maintenance	Mediation of waste, toxics and other nuisances	Mediation by biota	Bio-remediation by micro-organisms, algae, plants, and animals	*By amount, type, use, media (land, soil, freshwater, marine)*	Bio-chemical detoxification/decomposition/mineralisation in land/soil, freshwater and marine systems including sediments; decomposition/detoxification of waste and toxic materials e.g. waste water cleaning, degrading oil spills by marine bacteria, (phyto)degradation, (rhizo)degradation etc.
			Filtration/sequestration/storage/accumulation by micro-organisms, algae, plants, and animals	*By amount, type, use, media (land, soil, freshwater, marine)*	Biological filtration/sequestration/storage/accumulation of pollutants in land/soil, freshwater and marine biota, adsorption and binding of heavy metals and organic compounds in biota
		Mediation by ecosystems	Filtration/sequestration/storage/accumulation by ecosystems	*By amount, type, use, media (land, soil, freshwater, marine)*	Bio-physicochemical filtration/sequestration/storage/accumulation of pollutants in land/soil, freshwater and marine ecosystems, including sediments; adsorption and binding of heavy metals and organic compounds in ecosystems (combination of biotic and abiotic factors)
			Dilution by atmosphere, freshwater and marine ecosystems		Bio-physico-chemical dilution of gases, fluids and solid waste, wastewater in atmosphere, lakes, rivers, sea and sediments
			Mediation of smell/noise/visual impacts		Visual screening of transport corridors e.g. by trees; Green infrastructure to reduce noise and smells
	Mediation of flows	Mass flows	Mass stabilisation and control of erosion rates	*By reduction in risk, area protected*	Erosion / landslide / gravity flow protection; vegetation cover protecting/stabilising terrestrial, coastal and marine ecosystems, coastal wetlands, dunes; vegetation on slopes also preventing avalanches (snow, rock), erosion protection of coasts and sediments by mangroves, sea grass, macroalgae, etc.
			Buffering and attenuation of mass flows		Transport and storage of sediment by rivers, lakes, sea
		Liquid flows	Hydrological cycle and water flow maintenance	*By depth/volumes*	Capacity of maintaining baseline flows for water supply and discharge; e.g. fostering groundwater; recharge by appropriate land coverage that captures effective rainfall; includes drought and water scarcity aspects.
			Flood protection	*By reduction in risk, area protected*	Flood protection by appropriate land coverage; coastal flood prevention by mangroves, sea grass, macroalgae, etc. (supplementary to coastal protection by wetlands, dunes)
		Gaseous / air flows	Storm protection	*By reduction in risk, area protected*	Natural or planted vegetation that serves as shelter belts
			Ventilation and transpiration	*By change in temperature/humidity*	Natural or planted vegetation that enables air ventilation
	Maintenance of physical, chemical, biological conditions	Lifecycle maintenance, habitat and gene pool protection	Pollination and seed dispersal	*By amount and source*	Pollination by bees and other insects; seed dispersal by insects, birds and other animals
			Maintaining nursery populations and habitats	*By amount and source*	Habitats for plant and animal nursery and reproduction e.g. seagrasses, microstructures of rivers etc.
		Pest and disease control	Pest control	*By reduction in incidence, risk, area protected*	Pest and disease control including invasive alien species
			Disease control		In cultivated and natural ecosystems and human populations
		Soil formation and composition	Weathering processes	*By amount/concentration and source*	Maintenance of bio-geochemical conditions of soils including fertility, nutrient storage, or soil structure; includes biological, chemical, physical weathering and pedogenesis
			Decomposition and fixing processes		Maintenance of bio-geochemical conditions of soils by decomposition/mineralisation of dead organic material, nitrification, denitrification etc.), N-fixing and other bio-geochemical processes;
		Water conditions	Chemical condition of freshwaters	*By amount/concentration and source*	Maintenance / buffering of chemical composition of freshwater column and sediment to ensure favourable living conditions for biota e.g. by denitrification, re-mobilisation/re-mineralisation of phosphorous, etc.
			Chemical condition of salt waters		Maintenance / buffering of chemical composition of seawater column and sediment to ensure favourable living conditions for biota e.g. by denitrification, re-mobilisation/re-mineralisation of phosphorous, etc.
		Atmospheric composition and climate regulation	Global climate regulation by reduction of greenhouse gas concentrations	*By amount, concentration or climatic parameter*	Global climate regulation by greenhouse gas/carbon sequestration by terrestrial ecosystems, water columns and sediments and their biota; transport of carbon into oceans (DOCs) etc.
			Micro and regional climate regulation		Modifying temperature, humidity, wind fields; maintenance of rural and urban climate and air quality and regional precipitation/temperature patterns

Cultural Services

Cultural	Physical and intellectual interactions with biota, ecosystems, and land-/seascapes [environmental settings]	Physical and experiential interactions	Experiential use of plants, animals and land-/seascapes in different environmental settings	*By visits/use data, plants, animals, ecosystem type*	In-situ whale and bird watching, snorkelling, diving etc.
			Physical use of land-/seascapes in different environmental settings		Walking, hiking, climbing, boating, leisure fishing (angling) and leisure hunting
		Intellectual and representative interactions	Scientific	*By use/citation, plants, animals, ecosystem type*	Subject matter for research both on location and via other media
			Educational		Subject matter of education both on location and via other media
			Heritage, cultural		Historic records, cultural heritage e.g. preserved in water bodies and soils
			Entertainment		Ex-situ viewing/experience of natural world through different media
			Aesthetic		Sense of place, artistic representations of nature
	Spiritual, symbolic and other interactions with biota, ecosystems, and land-/seascapes [environmental settings]	Spiritual and/or emblematic	Symbolic	*By use, plants, animals, ecosystem type*	Emblematic plants and animals e.g. national symbols such as American eagle, British rose, Welsh daffodil
			Sacred and/or religious		Spiritual, ritual identity e.g. 'dream paths' of native Australians, holy places; sacred plants and animals and their parts
		Other cultural outputs	Existence	*By plants, animals, feature/ecosystem type or component*	Enjoyment provided by wild species, wilderness, ecosystems, land-/seascapes
			Bequest		Willingness to preserve plants, animals, ecoystems, land-/seascapes for the experience and use of future generations; moral/ethical perspective or belief

Appendix 2: Research Questionnaire Examples

Basic Pilot Questionnaire from CICES table (V4)

Ecosystem Service provision and condition					
Section	**Division**	**Group**	**Class**	**Present**	**Importance of Service**
Provisioning	Nutrition	Biomass	Cultivated crops		
			Reared animals and their outputs		
			Wild plants, algae and their outputs		
			Wild animals and their outputs		
			Plants and algae from in-situ aquaculture		
			Animals from in-situ aquaculture		
		Water	Surface water for drinking		
			Ground water for drinking		
	Materials	Biomass	Fibres and other materials from plants, algae and animals for direct use or processing		
			Materials from plants, algae and animals for agricultural use		
			Genetic materials from all biota		
		Water	Surface water for non-drinking purposes		
			Ground water for non-drinking purposes		
	Energy	Biomass-based energy sources	Plant-based resources		
			Animal-based resources		
		Mechanical energy	Animal-based energy		

Sample of questionnaire used for a small number of interviews with academic interviewees. Interviewees were asked to give an importance score of 1-3 for each service they considered to be presen

Questionnaire after adaptation from pilot

Age	
Place	
Occupation	
Connection to Area	
Years Experience at research site	
Highest Level Education	
Gender	
Nationality	
Interviewer	

Ecosystem Services Questionnaire Provisioning		Location:	Person:
Cultivated crops	1	Do local people grow food of their own near the research area? What kind of crops?	
Reared animals and their outputs	2	Do local people keep animals for food? Which ones?	
Wild plants, algae and their outputs	3	Which wild plants do people collect from the area and what do they use them for?	
Wild animals and their outputs	4	Which wild animals do people collect or hunt in the area and what do they use them for?	
Plants and algae from in-situ aquaculture /Animals from in-situ aquaculture	5	Is anything specially grown in the river or water system – for example fish farming?	
Surface water for non-drinking purposes / Ground water for non-drinking purposes	6	What is the main water source in the area? River, rain, piped, other	
Surface water for drinking Ground water for drinking	7	Is this the same for drinking water?	
Fibres and other materials from plants, algae and animals for direct use or processing	8	Do people use anything from the forest for making things – e.g. building, clothing material, baskets etc?	
Materials from plants, algae and animals for agricultural use	9	Do people collect anything from the area as fertilizer for crops or as food and bedding for animals?	
Genetic materials from all biota (DNA)	10	Is anything collected for medicinal use, or for example for captive breeding of wild animals?	
Plant-based resources Animal-based resources	11	Do people collect anything to use as fuel, such as wood, grass or dung for burning?	
Animal-based energy	12	Are animals used for physical labour?	

Regulating Services		
Bio-remediation by micro-organisms, algae, plants, and animals Filtration/sequestration/storage/accumulation by micro-organisms, algae, plants, and animals	**13**	Do you think there are plants and animals (micro-organisms) that help to keep the local environment clean by breaking down pollutants or toxic materials?
Filtration/sequestration/storage/accumulation by ecosystems	**14**	Do you think the whole area helps to keep the environment clean by absorbing or breaking down pollutants?
Dilution by atmosphere, freshwater and marine ecosystems	**15**	Is the river or water system important for doing this?
Mediation of smell/noise/visual impacts	**16**	Does the area do anything to make the environment less noisy or smelly?
Mass stabilisation and control of erosion rates	**17**	Is there a problem locally with erosion? What would happen if the forest wasn't here?
Buffering and attenuation of mass flows	**18**	Does soil and other material go into the river from the land?
Hydrological cycle and water flow maintenance Flood protection	**19**	Does this area affect the water quality and river flows?
Storm protection Ventilation and transpiration	**20**	Does the vegetation in this area (grass or trees, for example) give shelter from storms? Does it have an effect on the air quality?
Pollination and seed dispersal	**21**	Are there animals, birds and insects in the area that help with spreading seeds and pollinating crops?
Maintaining nursery populations and habitats	**22**	Are there important plants or animals here that don't grow in other places?
Pest control Disease control	**23**	Do you think there are more or less pests and diseases in this area than in other places, for example in the city?
Weathering processes Decomposition and fixing processes	**24**	What happens to deadwood and leaves? Are these good soils for things to grow in?

Chemical condition of freshwaters	**25**	How clean is the water from the area?
Global climate regulation by reduction of greenhouse gas concentrations / Micro and regional climate regulation	**26**	Do you think that this area affects the global climate? Does it affect the local climate?
Cultural Services		
Experiential use of plants, animals and land-/seascapes in different environmental settings Physical use of land-/seascapes in different environmental settings	**27**	Can people come here to do things like bird and wildlife watching, canoeing, hiking etc.? What things do they do?
Scientific	**28**	Is it an area that is important for scientific research?
Educational	**29**	Is it educationally important for other people or for schools, for example?
Heritage, cultural	**30**	Is this a historically or culturally important area?
Entertainment	**31**	Is the area advertised or used in the media (television, radio, internet, posters) at all?
Aesthetic	**32**	Is it beautiful?
Symbolic	**33**	Is the area itself, or plants or animals from here used as a symbol for anything?
Sacred and/or religious	**34**	Are there any special or sacred places in the area? Are there myths or stories about it?
Existence Bequest	**35**	Why do you think it is special? Is it important to preserve the area for future generations? Why?

Appendix 3

Site Visit Protocol

Permits

The research sites require permission for any research carried out. This project involves working with people, rather than collection of specimens and environmental data so does not necessarily fall under existing permissions. I am therefore required to obtain separate permissions, detailed below:

Siberia

No on-site visit will take place, all interviews are carried out with the help of Stanislav Ksenofontov, who has permission to work in the Chokurdakh area. Mr. Ksenofontov collected initial data for this project in his second field season.

China

Research permits are being obtained through Professor Bernhard Schmid, who has on-going research projects with NWIPB colleague Professor Jin-Sheng He. A research permit will be a requirement for obtaining a visa.

Laegern

I will liaise with the area foresters to ensure that all research complies with Swiss regulations for interviewing Canton employees.

Aldabra

I am currently applying through the Seychelles Islands Foundation and Seychelles Bureau of Standards for permission to carry out my research, as it does not fall under the current ZARP/SIF agreement.

Lambir Hills

The URPP GCB has a memorandum of understanding with the National Park, which also covers my work. I also liaise with the Head Ranger to ensure that the work is formalized with Sarawak Forestry.

Danum Valley

After a first 'Look-See' visit permit, I worked with Yayasan Sabah to have a local collaborator (probably Dr. Waidi Sinun) for a second visit, although ultimately I did not return for another season.

Pasoh

As with Lambir Hills, the URPP has a Memorandum of Understanding, which allows me to work in the FRIM research sites. This is also through liaison with the Site Manager, Christine Fletcher.

Fieldwork

Questionnaires

With researchers, using the CICES framework:

- Does your research site deliver any of these services?
- How important do you think the service is (Low, Medium, High)?

With local experts using a reworded CICES framework (translated to Chinese, Russian and German):

- Does your research site deliver any of these services?
- How important do you think the service is (Low, Medium, High)?

Research Narrative

When discussing the context of my work and consequently the reasons for and future use of the information collected from interviewees, I provide the following narrative, which may vary slightly depending on the scientific knowledge of the interviewee. For example, most interviewees are not familiar with the concept of ecosystem services, so I do not use this terminology but with those who are, then I may make reference to the concept of benefits and services. In general, this level of knowledge becomes apparent during the interview.

I want to understand, from the point of the view of people who live and work at the site, why it is or is not important for them. Specifically what plants, animals or other things about the area are important (beneficial) for people and how. I would like to know what is positive and negative about living and/or working there. This will help me to build a picture about the research area and the people who live in or use it. I can then understand whether there are threats to this area and what local people think about those threats so that we can think about how to look after the area into the future.

Data (knowledge) sharing

Some of the data for my PhD project will be generated from knowledge held by local expert interviewees. I will therefore ensure that I have free, prior and informed consent (United Nations, 2008) from participants to use that data.

In addition, and as a condition of a number of the research permits, all the data collected will be available to the local partner organization as required. Most permits require that I produce a short report of the work carried out. There are in addition provisions within the URPP GCB for translation services of documents for partners as needed.

I have verified that the regulations for the two existing University of Zürich ethics committees (the Faculty of Philosophy, Faculty of Medicine – including Cantonal Research Commission) do not apply to this project. Through discussion with supervisors, colleagues and with reference to the literature I have made sure that I am following an ethically accepted format for this work.

Confidentiality

While there are key contacts listed here, all participants will be asked for their consent to be identified or not in the research. In cases where participants want to remain anonymous, the names will be removed and replaced with a number identifier that is only known to myself.

It is not possible in this work to anonymise the location of the research but no one individual will be referred to, rather an aggregation of all information taken from 'local experts'.

In cases where there is a need to share the raw data, all participants will be anonymised. No pictures of individuals will be included without their consent and the consent of managing organisations, and only where it does not prejudice participants.

Potential outcomes for participants

Consideration will be given to potential outputs that are relevant for the organisations that are involved with the interview process. The following list is not prescriptive as outputs will be discussed throughout the research with participants. However, these might include:

- A basic report on the state of ecosystem services at their site, with an indication of knowledge gaps that might be further pursued
- A simple map of the stocks and flows of ecosystem services
- An up to date site map – some organisation do not currently have this
- Translations of the final PhD Chapters, as required.

General reference: (Crow and Wiles, 2008)

Appendix 4

Ecosystem services included in analyses

ES	Uncertainty (categorical)	Disagreement (binary)	Description
esv01	-	-	Experiential use of plants, animals and land-/seascapes in different environmental settings
esv02	✔	-	Physical use of land-/seascapes in different environmental settings
esv03	-	-	Scientific
esv04	✔	-	Educational
esv05	✔	✔ H	Heritage, cultural
esv06	✔	-	Entertainment
esv07	-	-	Aesthetic
esv08	✔ H	✔	Symbolic
esv09	✔ H	✔ A H	Sacred and/or religious
esv10	✔ H	-	Existence
esv11	-	-	Bequest
esv12	-	✔	Cultivated crops
esv13	-	✔	Reared animals and their outputs
esv14	-	✔ A	Wild plants, algae and their outputs
esv15	✔ H	✔	Wild animals and their outputs
esv16	✔ H	-	Plants and algae from in-situ aquaculture
esv17	✔ H	-	Animals from in-situ aquaculture
esv18	✔ H	✔	Surface water for drinking
esv19	✔ H	✔ H	Ground water for drinking
esv20	✔	✔ H	Fibres and materials from plants, algae, animals for direct use or processing
esv21	✔	✔ A	Materials from plants, algae and animals for agricultural use
esv22	✔ H	-	Genetic materials from all biota (DNA)
esv23	-	✔	Surface water for non-drinking purposes
esv24	-	✔	Ground water for non-drinking purposes
esv25	✔ A	✔ A	Plant-based resources
esv26	✔ A	-	Animal-based resources
esv27	✔	✔ H	Animal-based energy

esv28	✔	✔	Bio-remediation by micro-organisms, algae, plants, and animals
esv29	✔	✔ A	Filtration/sequestration/storage/accumulation by micro-organisms, algae, plants, animals
esv30	✔	✔ A	Filtration/sequestration/storage/accumulation by ecosystems
esv31	✔	✔	Dilution by atmosphere, freshwater and marine ecosystems
esv32	✔	✔	Mediation of smell/noise/visual impacts
esv33	✔	✔ H	Mass stabilisation and control of erosion rates
esv34	✔	✔ A H	Buffering and attenuation of mass flows
esv35	✔	✔ A	Hydrological cycle and water flow maintenance
esv36	✔ H	✔ H	Flood protection
esv37	✔	✔ A	Storm protection
esv38	-	✔ A H	Ventilation and transpiration
esv39	✔	-	Pollination and seed dispersal
esv40	✔ H	✔ H	Maintaining nursery populations and habitats
esv41	✔ H	✔ A	Pest control
esv42	✔ H	✔	Disease control
esv43	✔	✔	Weathering processes
esv44	✔	✔	Decomposition and fixing processes
esv45	✔	✔	Chemical condition of freshwaters
esv46	✔ A	✔ A H	Chemical condition of salt waters
esv47	-	✔	Global climate regulation by reduction of greenhouse gas concentrations
esv48	✔	-	Micro and regional climate regulation

Cultural services are brown cells, provisioning are green, and regulating are blue. Ticks (✔) indicate services that were uncertain or disagreed about at one or more of the research sites. Most analyses of these uncertainty and disagreement were carried out for Aldabra (A) and Haibei (H). All services were included in the ordinal data

Appendix 5

Services showing some effect of explanatory variables:

Ordinal Data

Only site

18 (surface water for drinking),

30 (filtration, sequestration, storage, accumulation by ecosystems)

43 (weathering processes)

Site with (.) for one other variable

(27 (animal-based energy))

(28 (bioremediation by micro-organisms))

(32 (mediation of smell, noise, visual impacts))

(44 (decomposition and fixing processes))

(48 (regional climate regulation))

Site equally significant

12 (crops) site and vis

08 (symbolic) gen and site

37 (storm protection) slight site, ed, occn = equal

Site but another more significant variable

07 (aesthetic) site but **occn** was most significant

22 (genetic materials) site slightly but **ed**, **occn** and **local** all more signif, with **yexp** most

42 (disease control) site slightly but **age** more signif

No site

10 (existence) – no significant variable

11 (bequest value) slight **ed**

41 (pest control) slight effect **vis**

46 (chemical condition of salt waters) slight **conx**

Appendix 6

Supplementary Data for Chapter 3

Q1 Supplementary figure S1

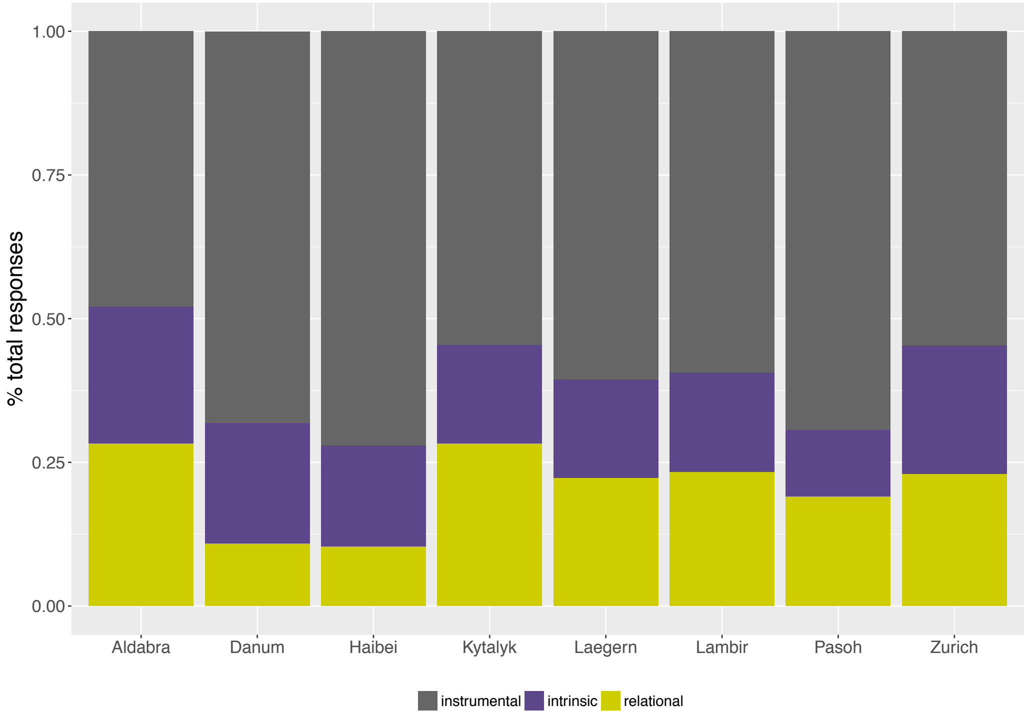

Figure S1: Percentage of responses that reference the three broad categories of values for each research site. Groups of values normalised to one across the research sites.

Q3 Supplementary figure S2

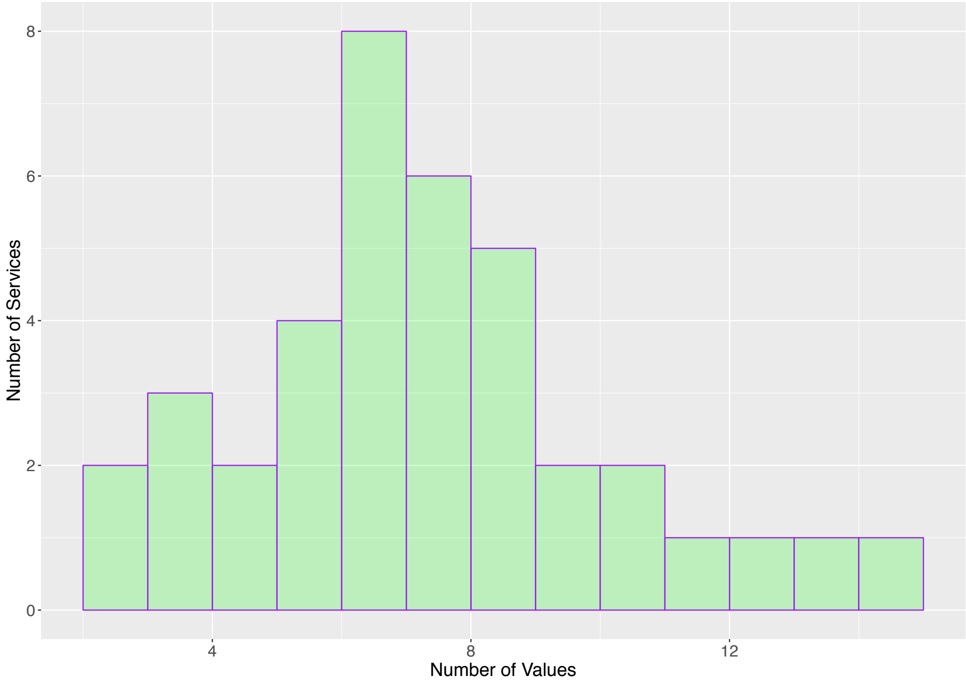

Figure S2: Distribution of the number of values across 38 ecosystem services. Minimum number of values = 3; maximum = 15

Q4 Supplementary figures S3-S7

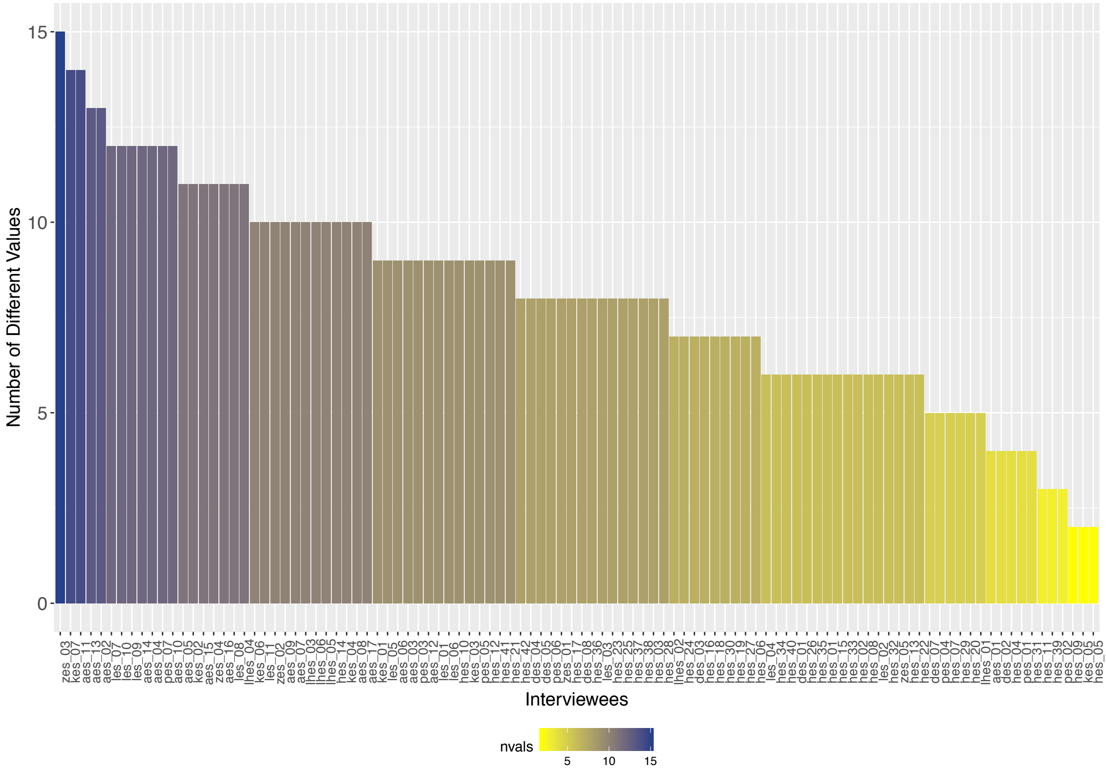

Figure S3: The diversity of values revealed by interviewees, with a maximum of 15 possible values in total. Only one interviewee expressed all value types. A further 30 people expressed at least two thirds of the values (ten or more).

Occupation

Figure S4a shows the absolute number of responses from interviewees in different occupations. S4b shows the proportional number of responses. 98 interviewees are represented here. The number of people in each occupation vary, and the occupation groupings combine other types of employment, as follows: academics (acme) are interviewees working as postdoctoral researchers (5), academic group leaders (5) and professors (5), and whose research is specifically related to the research site being discussed. Management (mgt) positions encompass those interviewees who have a direct role in managing the site. They comprise one chief executive officer, and ten site managers. Site-officers (off) are other staff working at the research site, with one engineer, nine technicians, one administrator and 11 officers, mostly rangers. Researchers (rchr) consist of 31 student researchers and 12 research assistants. Six teachers (tchr) were also interviewed and one member of the public (other) linked to the local school whose profession was none of the above.

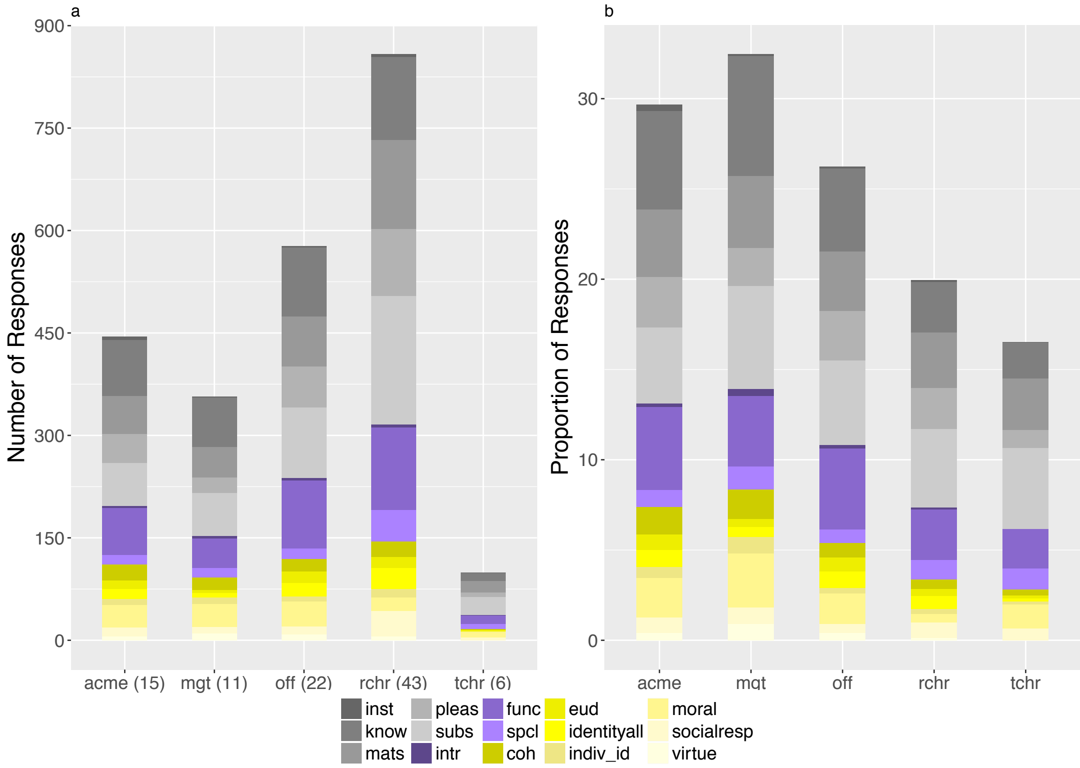

Figure S4: Values expressed by interviewees divided by occupation type: academic, manager, site officer, researcher and teacher. (a) is absolute numbers, (b) is the proportion when adjusted for the number of interviewees in each group, shown in brackets, (a).

Once I correct the responses for the number of interviewees in each occupation, the proportion of responses from researchers reduces, with an increase in response rate from managers, academics and site officers. The proportional data shows that academics and site managers reveal more relational values than interviewees in other occupations. Site officers mentioned a higher proportion of instrumental values.

Education Level

The responses about values from interviewees with differing maximum levels of education are shown in figure S5a. Seven people did not provide this information, and were excluded from the analysis, leaving 95 interviewees. Within each level, there are different numbers of interviewees. Three people who attended only primary or middle school (p_sch), and seven people completed up to high school level (h_sch). Six people attended college (coll) after school, with five people having completed their undergraduate degrees (bsc). Thirty-five people were educated to Masters level (msc) and 39 had completed doctorates (phd).

When the responses are adjusted for the number of people in each group (figure S4b), the responses from people who have attended college and high school increase in number, while the responses from those educated to Master and Doctorate are less numerous.

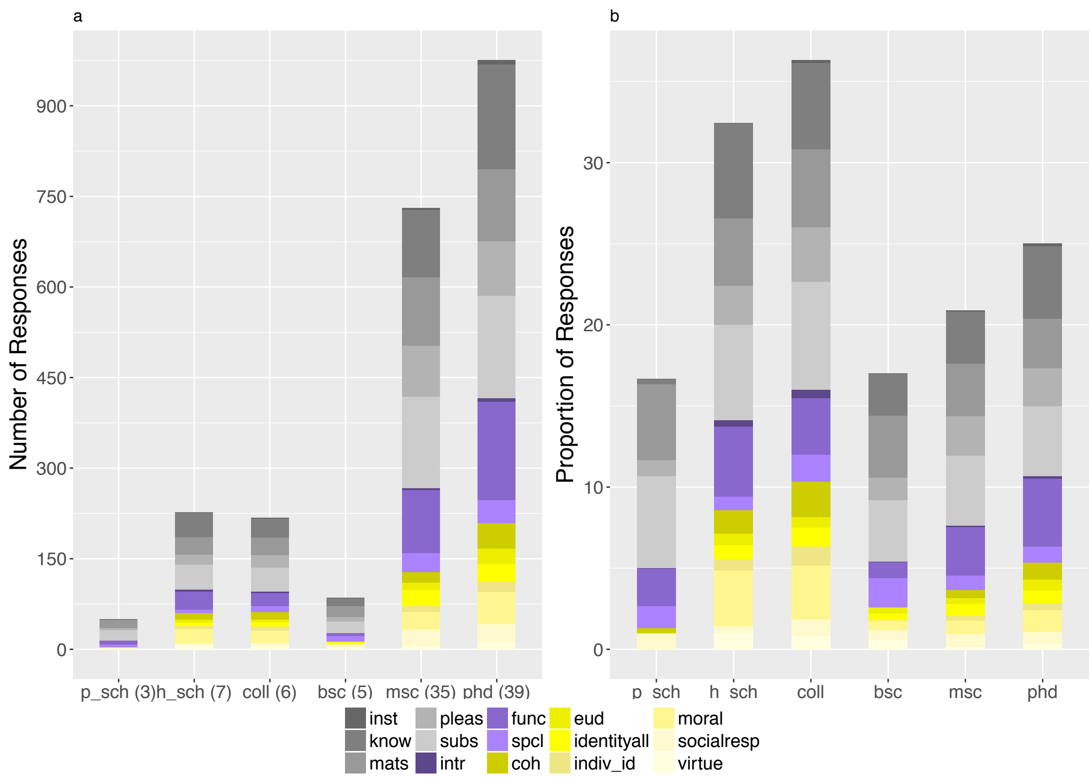

Figure S5: Values given by interviewees split by maximum education level: primary school, high school, college, bachelor degree, masters degree, doctorate. (a) is absolute numbers, (b) is proportion adjusted for the number of people in each group, shown in brackets, (a).

Gender

The responses of 101 interviewees are included for analysis related to gender, with one interviewee not providing this information. There are a total of 40 responses from people identifying as female, and 61 responses from those who identify as male. The division of absolute and proportional responses between these two groups is shown in figure S6. Once differences in group size is accounted for, there are proportionally more responses about values from women than from men.

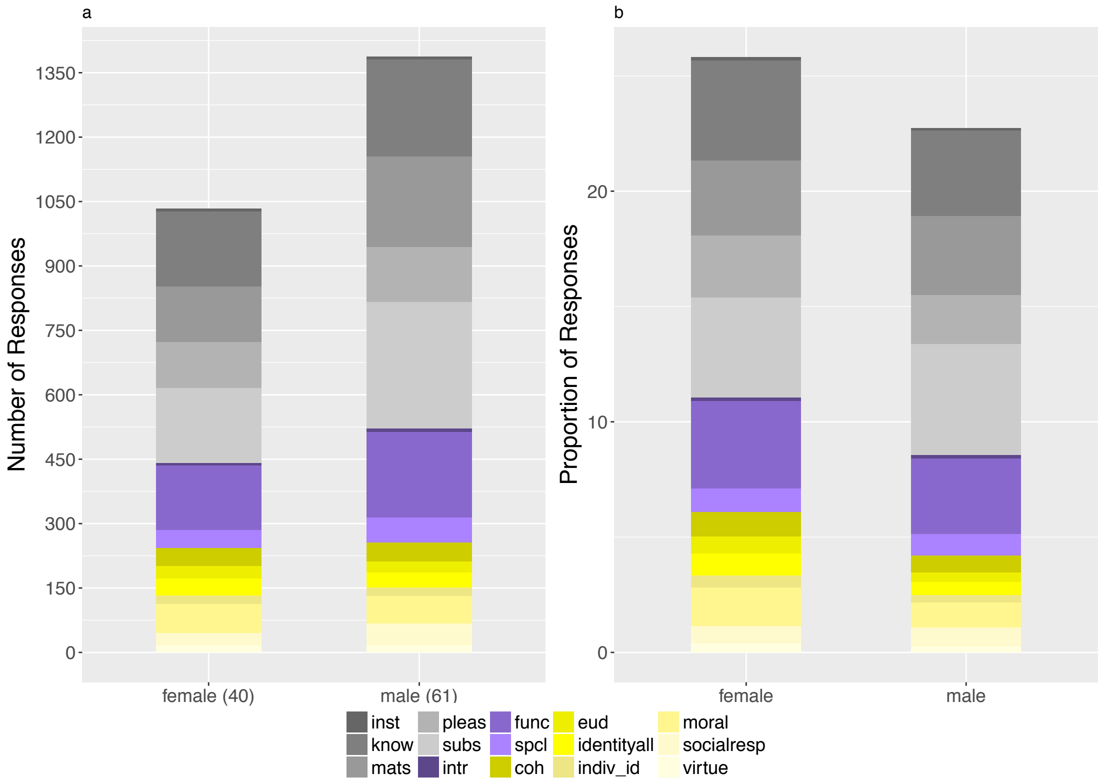

Figure S6: Values expressed by interviewees partitioned by gender. (a) shows absolute numbers, (b) is the proportion when adjusted for number of interviewees in each group, shown in brackets, (a).

Age Class

One of the 102 interviewees did not provide information about age. Thirty-four people were aged 20-29, 36 were 30-39, and 23 were 40-49. Six people were in the 50-59 group and a further 2 were aged 60 or above. The adjusted data suggests that older interviewees mentioned values more often than younger interviewees.

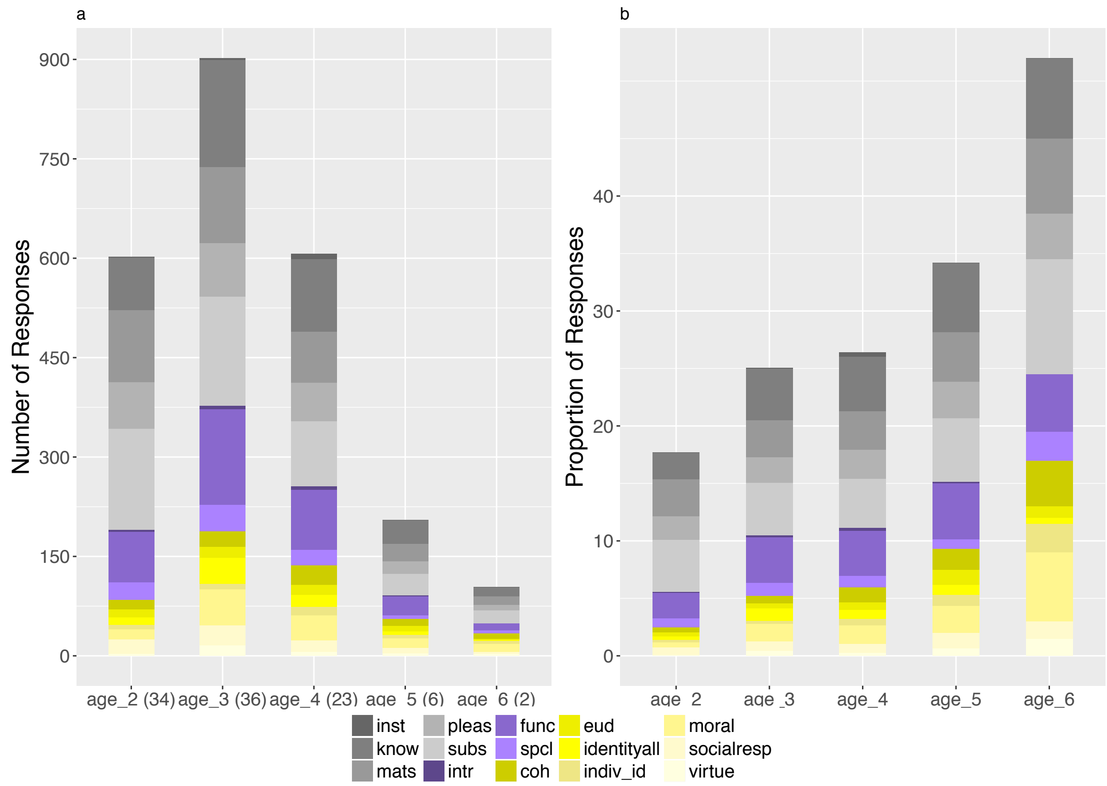

Figure S7: Values expressed by interviewees partitioned by age class.(a) shows absolute numbers, (b) is the proportion when adjusted for number of interviewees in each group, shown in brackets, (a).

Visited the Site

Only four of the 100 people that gave information about whether or not they had visited the site indicated that they hadn't. I therefore did not analyse this attribute.

Q5 Supplementary figures S8-S11

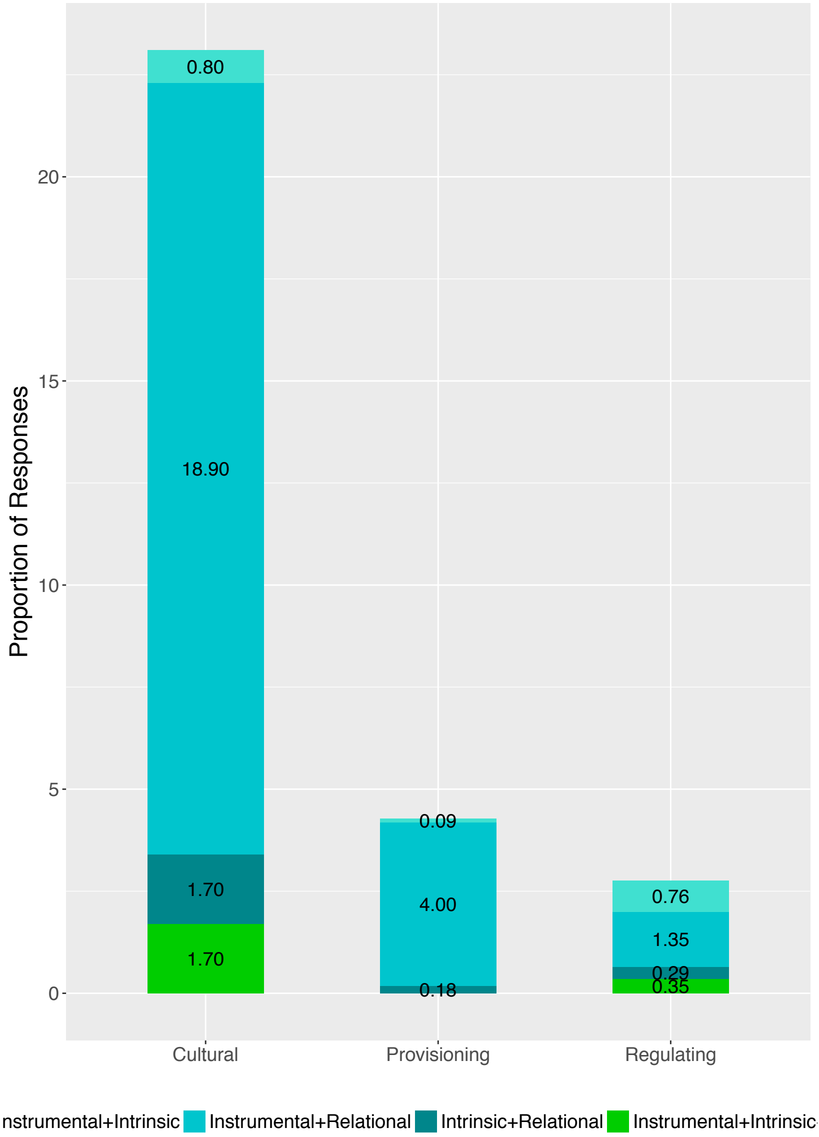

Figure S8: Shows double and trip coding for ecosystem service sections, adjusted for the number of questions in each section. The 10 questions for cultural services elicit high numbers of multiply coded responses, while the 11 questions about provisioning services
elicit slightly more mentions of value than the 17 regulating ones.

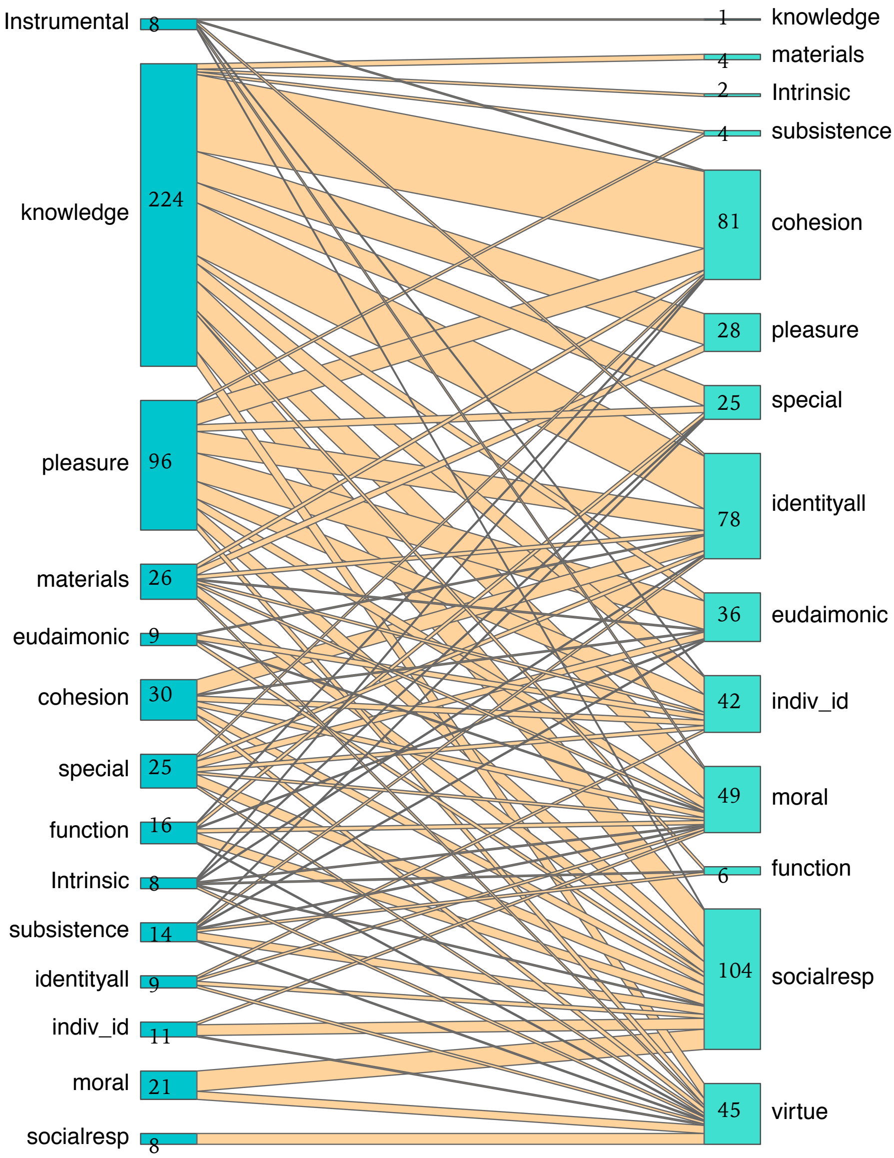

Figure S9: Bipartite network of values that occur together in the same response about cultural ecosystem services. 505 connections.

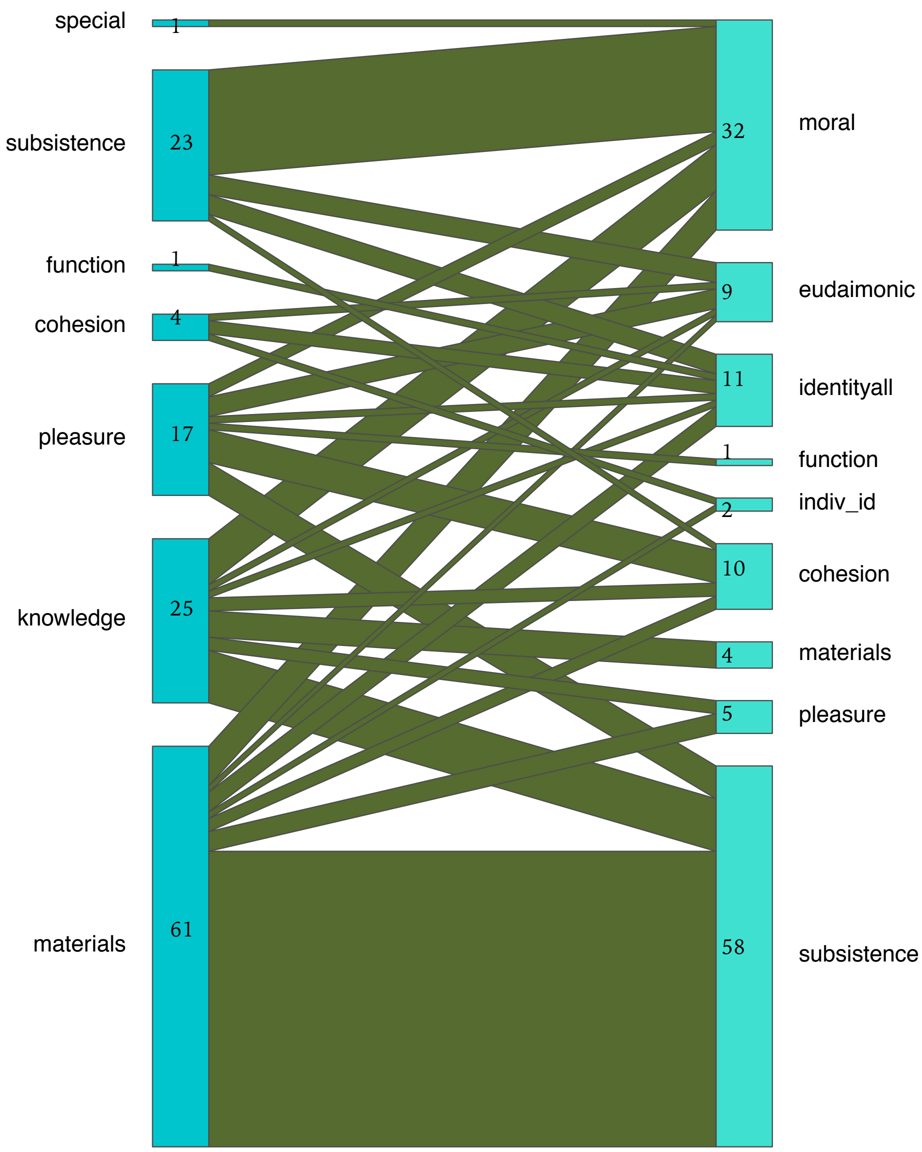

Figure S10: Bipartite network of values that occur together in the same response about provisioning ecosystem services. 132 connections.

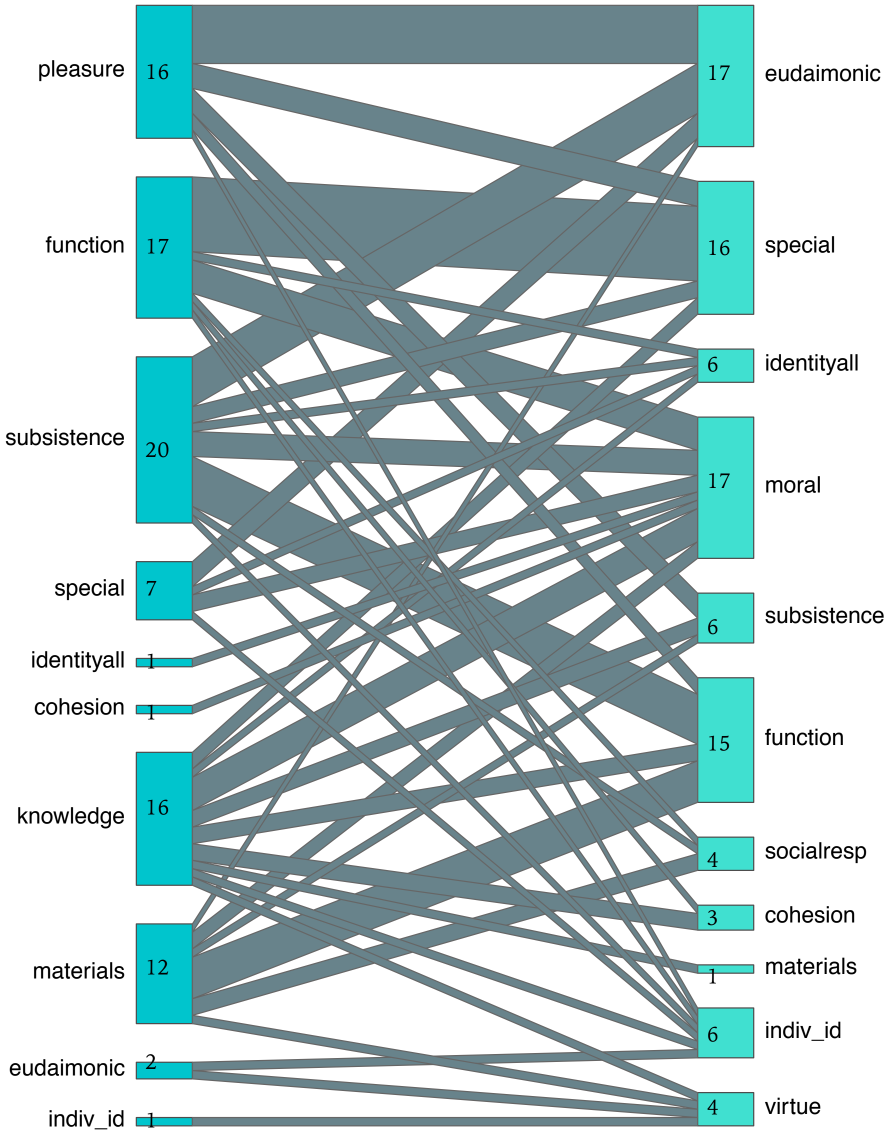

Figure S11: Bipartite network of values that occur together in the same response about regulating ecosystem services. 93 connections.

Q5 Supplementary figures S12-S26

Figures S12-S26 show the numbers of double codes for the fifteen ecosystem services with the highest numbers of dual codes from individual responses.

Figure S12: ESV02 – Physical and experiential use

	moral	cohesion	pleasure	eudaimonic	indiv id	virtue	subsistence	function	identityall	special
knowledge	5	3	7	1	2	1	1	1		
pleasure	4	7		3	1	1	1		1	1
cohesion	1				1					
materials			2							
subsistence	1					1				
function				1						
moral						1				

Figure S13: ESV03 – Scientific

	cohesion	special	indiv id	virtue	Intrinsic	socialresp
knowledge	5	3	2	2	1	1
special			1	1		
Intrinsic		1				

Figure S14: ESV04 - Educational

	cohesion	moral	eudaimonic	indiv id	virtue	identityall	pleasure	special
knowledge	14	5	3	3	2	1	3	3
cohesion			1	1		2		
special	1	2	1					
pleasure		1			1			
identityall				1				
indiv id					1			
moral					1			

Figure S15: ESV05 – Heritage, Cultural

	identityall	cohesion	socialresp	indiv id	moral	special	virtue	knowledge	materials	pleasure	subsistence
knowledge	9	12	1	1	2	1	1		1	1	1
cohesion	3		1		1		1				
pleasure	3	1		1		1					
Instrumental	1	1						1			
materials	1	1	1								
identityall			1								
special				1							
subsistence	1										

Figure S16: ESV06 - Entertainment

	cohesion	identityall	pleasure	special	virtue	function
knowledge	9	1	5	1	1	1
pleasure	5	3				
cohesion		3			1	
function	1			1		
special	1					

Figure S17: ESV07 - Aesthetic

	eudaimonic	indiv id	identityall	virtue	pleasure	socialresp	special	cohesion	moral
pleasure	14	6	2	1		1	2		1
eudaimonic		3							
knowledge			1		1			1	
materials	1	1			1				
moral				1		1			
identityall		1							
socialresp				1					
special	1								

Figure S18: ESV08 - Symbolic

	identityall	cohesion	indiv id	eudaimonic	materials	pleasure	special
knowledge	17	5	1	1	2	1	1
pleasure	2	2					
cohesion	2		1				
materials	1	1	1				
special	1			1			
eudaimonic	1						

Figure S19: ESV09 - Spiritual

	identityall	moral	cohesion	indiv id	eudaimonic	pleasure
knowledge	8	2	3			1
pleasure	2	1	1	2	1	
identityall		2				
cohesion	1					
eudaimonic				1		
materials	1					
special					1	

Figure S20: ESV10 - Existence

	virtue	identityall	socialresp	moral	special	indiv id	pleasure	eudaimonic	function	subsistence
knowledge	2	2	1	2	5	1	2		1	
pleasure	1	2	2			3		1		1
Intrinsic	2	1		1					1	
function	1			2	1					
subsistence		1	2					1		
special	1	2								
identityall	2									
eudaimonic			1							
indiv id			1							
Instrumental				1						
materials							1			
moral	1									

Figure S21: ESV11 - Bequest

	socialresp	virtue	moral	cohesion	eudaimonic	indiv id	special	pleasure	function	identityall	Intrinsic	materials
knowledge	23	2	5	4	1	2	1	2			1	1
moral	13	2										
materials	7	2	2	1				1				
pleasure	8	1			2		1			1		
special	8				1	1						
function	7		1				1					
socialresp		7										
subsistence	4						1		2			
cohesion	4	1	1									
indiv id	5		1									
Instrumental	1		1			1				1		
eudaimonic	2		1									
identityall	2											
Intrinsic	1			1								

Figure S22: ESV14 – Wild plants

	subsistence	moral	eudaimonic	cohesion	identityall
subsistence		4	1	1	1
materials	6				
pleasure	3		2	1	
knowledge	2				1

Figure S23: EV15 – Wild animals

	moral	subsistence	materials	cohesion	eudaimonic	pleasure
knowledge	4	5	3			1
subsistence	9				1	
materials		8				
pleasure	2	2		1		

Figure S24: ESV20 – Fibres for processing

	identityall	moral	indiv id	cohesion	subsistence
materials	3	4	1	1	1
cohesion	1		1		
subsistence	1				

Figure S25: ESV27 – Animal-based energy

	cohesion	eudaimonic	identityall	pleasure	materials
knowledge	1	1		1	1
pleasure	2	1	1		
materials	1	1		1	
cohesion		1	1		

Figure S26: ESV40 – Maintaining nursery populations

	special	moral	function	identityall	eudaimonic	virtue	materials
function	6	2		1			
knowledge	1	2	1				1
subsistence	1	1	2	1			
special		2		1	1		
materials					1	1	
pleasure	1		1				
eudaimonic						1	
identityall		1					

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Publications

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